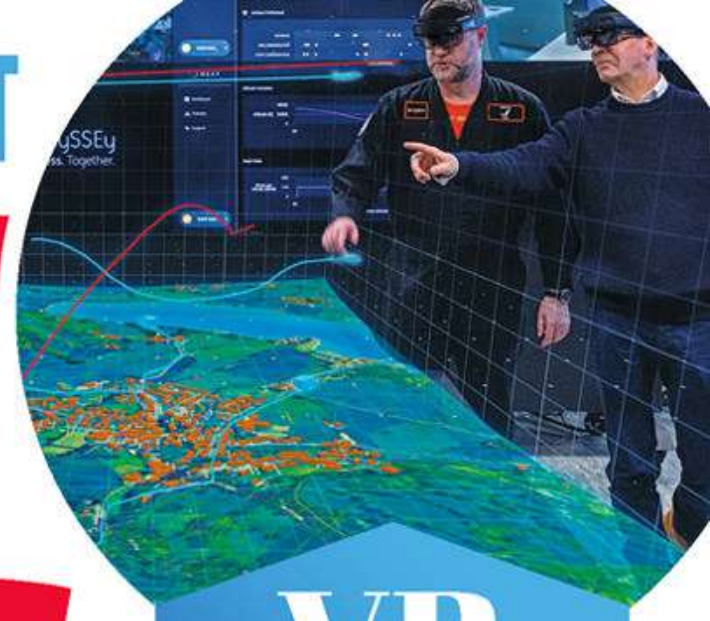
WHY WE'RE MADE OF STARDUST

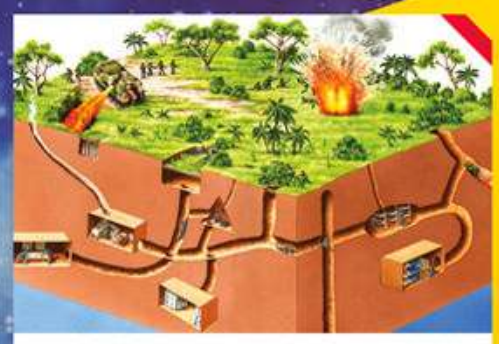
HOW IT WORKS



VR BATTLEFIELD TRAINING

DISCOVER YOUR SIXTH SENSE

DO YOU PERCEIVE THE WORLD AROUND YOU IN WAYS OTHER PEOPLE CAN'T?



12 SECRET UNDERGROUND STRUCTURES

WHY THIS PLANT CHANGED LIFE ON EARTH

HOW PACIFIC ISLANDERS CONQUERED THE OCEAN

WHAT MAKES CHOCOLATE SO ADDICTIVE?

FUTURE

ISSUE 185

+ WHAT IS SEA FOAM? / SOUNDPROOFING SCIENCE / HOW HADRIAN'S WALL WAS BUILT / DO COWS HAVE FOUR STOMACHS?

Advertisement

YOUR PET CALLS THE SHOTS. PET INSURANCE IS YOUR CALL.

Get more info or compare quotes at go.compare/pet-insurance

GO. COMPARE

WELCOME

Issue 185

"Tetrachromacy allows people to see the world in around 100 times more colours and shades than average"

SCAN HERE TO SUBSCRIBE TO **LIVESCIENCE'S** NEWSLETTER

Discover your sixth sense
PAGE 26

HIGHLIGHTS

30 SECRET SMELLS
Take a journey through your nasal passages

54 GOING GREEN
The evolution of grass has changed the planet

74 VIRTUAL WAR
Directing a battlefield simulation in VR

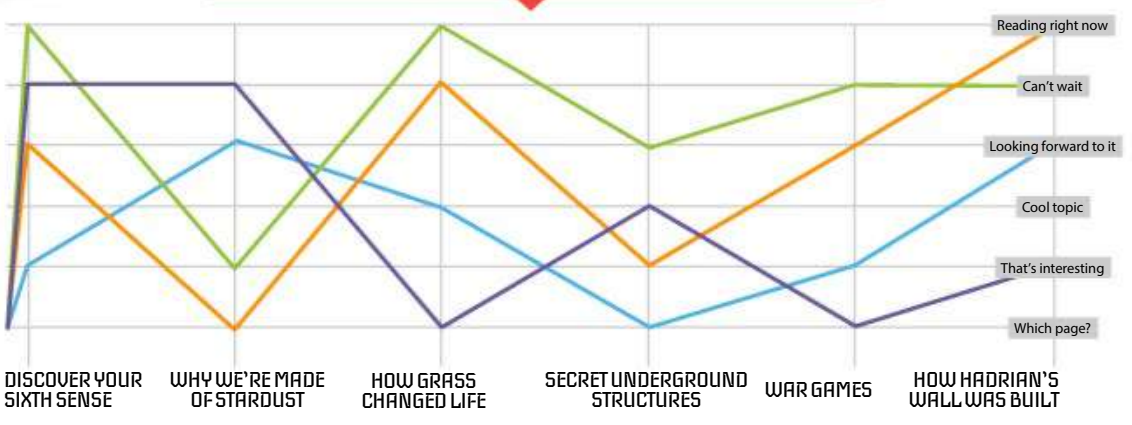
SUBSCRIBE NOW

GO TO PAGE 24 FOR GREAT DEALS

Have you ever been told that you've got eyes in the back of your head? Do you have a heightened sense of taste? Maybe you're one of the exceptional few with synesthesia, meaning you can see smells, taste colours or some other simultaneous sensory combination. In this issue of **How It Works**, we explain how your everyday senses of sight, smell, touch, taste and hearing work, then delve into the world of other senses and perceptions that you might not even realise you have. Some of these super senses can be explained, but scientists don't fully understand others – they can seem quite spooky and almost supernatural. Turn to page 26 to discover whether you're experiencing the world differently to most. Hope you enjoy the issue!

Ben Biggs
EDITOR

WHAT WE'RE ANTICIPATING



NIKOLE
PRODUCTION EDITOR

SCOTT
SENIOR STAFF WRITER

AILSA
STAFF WRITER

DUNCAN
SENIOR ART EDITOR

FOR EXCLUSIVE **HIW** NEWS AND OFFERS, SIGN UP TO OUR MAILING LIST HOWITWORKSDAILY.COM/NEWSLETTER

© Getty

INSIDE

Issue 185

SPECIAL

26 Discover your sixth sense
Uncover the science behind your five senses – plus others that you may not have known you had

TRANSPORT

34 Exploring the Pacific
Hop aboard the ancient sailing vessels that carried new nations across the ocean

SPACE

38 Why we're made of stardust
Human beings, and everything else, are made from recycled elements that came from the stars

44 What happens during a lunar eclipse?
Why total lunar eclipses turn our natural satellite red

REGULARS

06 Global eye
Science and tech news from around the world

22 Wish list
Health and fitness gadgets

84 Braindump
Your questions answered

90 Book reviews

92 Brain gym
Give your brain a workout with our puzzle pages

94 How to...
Replicate tooth decay using eggs and juice

96 Letters
Have your say

98 Fast facts

SCIENCE

46 Soundproofing in action
Noise can be a real nuisance in the wrong place, but the volume can be turned down using the right shapes and materials

48 The science of chocolate
Why each bite of this delicious confectionary contains a complex mixture of components that affects your body in many ways

50 Know your true age
Why different parts of our bodies are grow older at different rates

ENVIRONMENT

52 How grass changed life
This tiny green plant has influenced Earth's climate and the evolution of animals

56 Why cows have four stomach chambers
Peer past a bovine's grinding teeth and into its unusual digestive system

58 How dung beetles clean the Savannah
Discover the lives of these natural waste-removal insects and their fascination with faeces

60 What is sea foam?
Ocean decay and pollution contribute to this frothy lining on Earth's oceans

62 Anatomy of a sinkhole
These pits can appear when the ground's surface collapses

HISTORY

64 Secret underground structures
Discover historic hidden worlds carved out of the ground

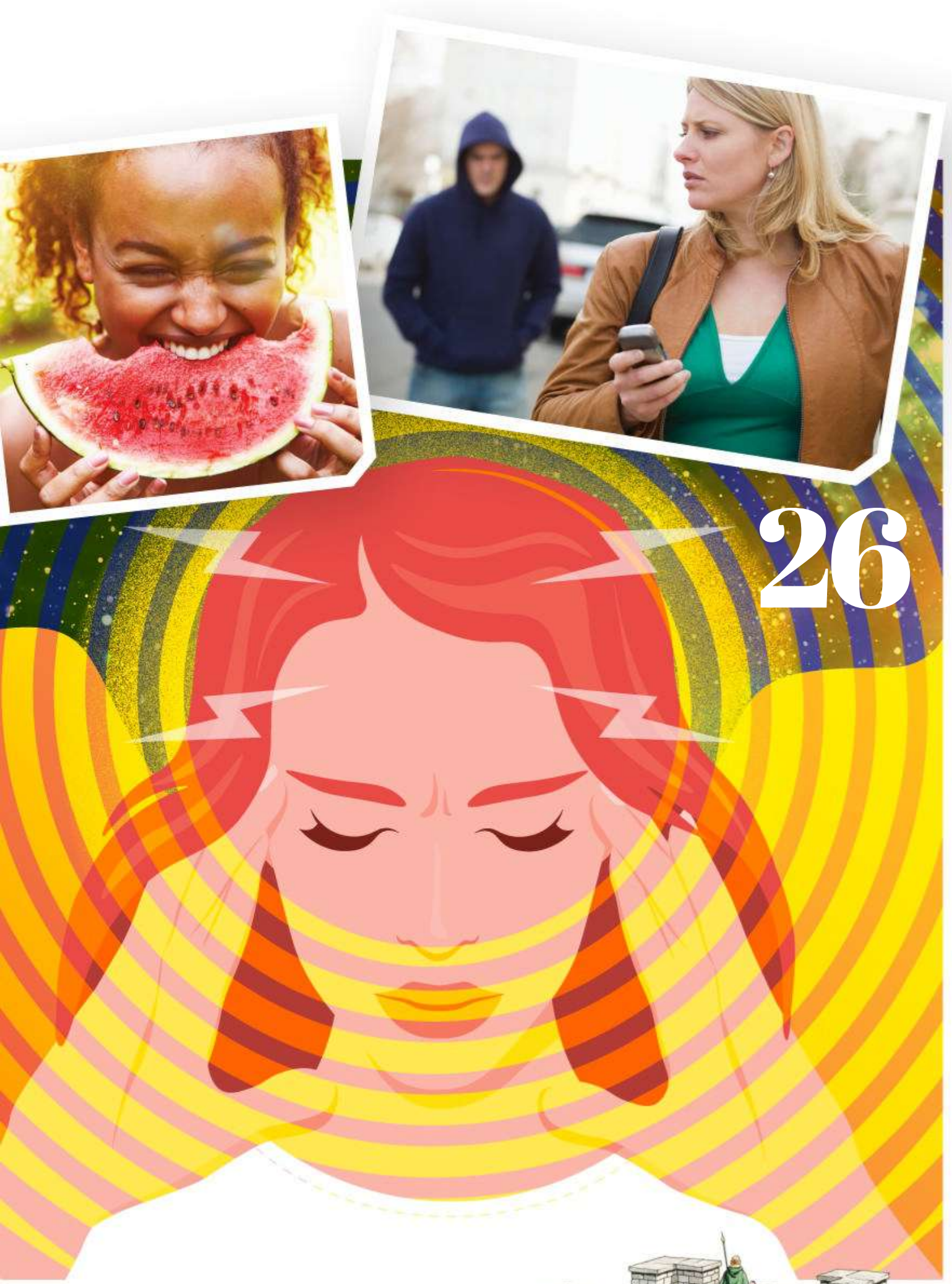
70 Building Hadrian's Wall
How the Roman Empire used artful engineering and widespread influence to forge this snaking wall across Britain

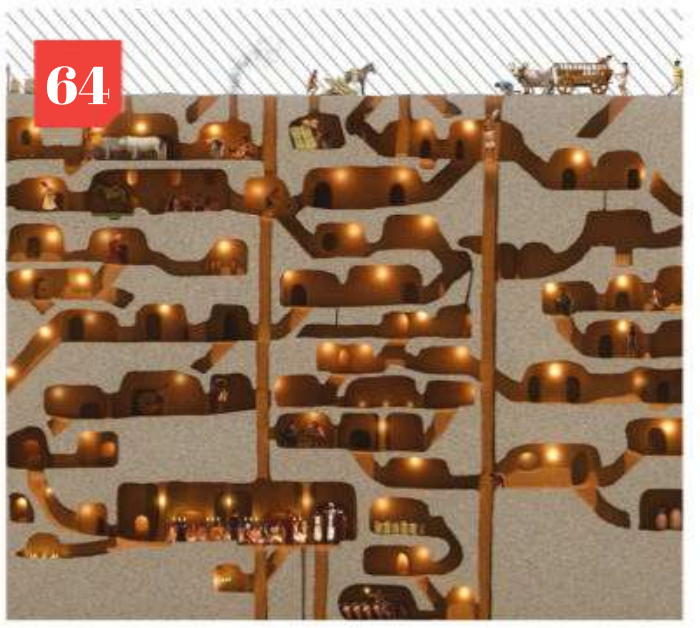
TECHNOLOGY

72 War games
How virtual and augmented reality technology are being used as a sophisticated military training tool

78 How USB drives work
The humble flash drive reinvented the way we store and transfer computer files

80 Materials that will change everything
From road surfaces to the surface of our skin, the materials revolution is here





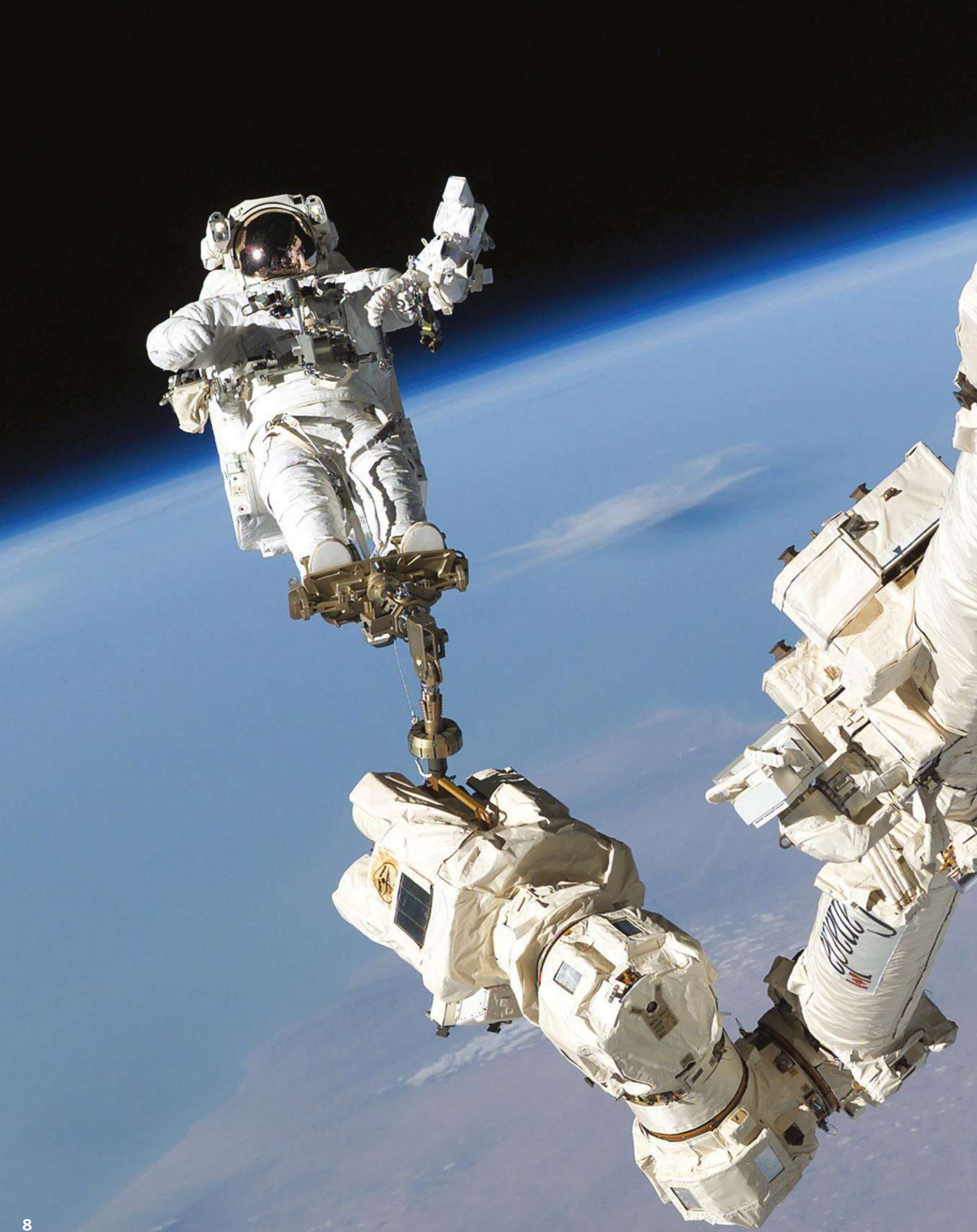
SUBSCRIBE NOW
GO TO PAGE 24 FOR GREAT DEALS

WHY WE'RE MADE OF STARDUST
HOW IT WORKS
VR BATTLEFIELD TRAINING
DISCOVER YOUR SIXTH SENSE
WHAT MAKES CHOCOLATE SO ADDICTIVE?

Salty science

This scanning electron microscope image reveals the cubic shape of salt crystals. Salt is made up of two ions – positively charged sodium atoms and negatively charged chloride atoms. When these elements come together to form sodium chloride, or salt, the chloride ions are attracted to the sodium ions and arrange themselves together into a cubic lattice structure.

© Getty



On top of the world

This is Stephen K. Robinson on his third extravehicular activity in 2005. This was part of the first mission since the Space Shuttle Columbia disaster in 2003, which killed seven astronauts. While anchored to the Canadarm 2 robotic arm, Robinson completed several tasks, including installing an external stowage platform for spare parts outside the International Space Station.

© NASA; Robinson canadarm

Building an ant bridge

In the tropical forests of Australia and throughout Asia, troops of weaver ants march through the foliage on the hunt for insect prey and to find new nests. When a group of ants finds a suitable leafy structure to call home, they create body bridges, like the one seen in this image, that act as a winch to pull the leaves together before they stitch them using silk secreted by ant larvae.

© Shutterstock

Celebrating science

Once a year, people from around the world travel to the Phra Nakhon Khiri Festival in Thailand to celebrate the history of Phetchaburi province and honour King Rama IV of the Chakri Dynasty, who's referred to as the father of Thai science. Over several days of the festival, hundreds of fireworks are launched around Phra Nakhon Khiri Historical Park and palace, as seen in this image.

© Getty

Great white sharks have been recorded diving over 1,000 metres into the ocean's midnight zone

ANIMALS

Huge sharks hang out in the twilight zone

WORDS **CARYS MATTHEWS**

Large marine predators including great white sharks regularly spend time in the ocean's twilight and midnight zones, far beneath the depths at which they feed, in a discovery that has mystified scientists. In a new study, data from 12 species of large predatory fish, including sharks, billfish and tunas, showed they regularly spent time in the mesopelagic zone, also known as the twilight zone, which stretches between the depths of 200 to 1,000 metres. They were also seen in the midnight zone, 1,000 to 3,000 metres beneath the ocean's surface. "How, when and where they access the deep ocean certainly varies, but the clear anecdotal answer is that the deep ocean seems like an important habitat, regardless of the predator species," said Camrin Braun, an assistant scientist at the Woods Hole Oceanographic Institution (WHOI).

As part of the new study, researchers matched the diving patterns of 344 electronically tagged predatory fish, including great white sharks, tiger sharks, whale sharks, yellowfin tuna and swordfish, with shipboard sonar over a cumulative period of 46,659 days to identify which species regularly deep dive into the twilight and midnight zones.

Their findings showed a correlation between dives and the location of the deep scattering layer. This ocean layer is so densely packed with small fish and other marine organisms it is sometimes mistaken for the seafloor. Creatures of the deep scattering layer rise up to the surface at night to feed, then sink back down to the twilight zone in the day. This suggests that marine predators feed on animals in the deep scattering layer. However, the team also discovered many dive far deeper than the deep scattering layer extends, for reasons unknown. Great white sharks dive as deep as 1,128 metres, whale sharks to 1,912 metres and swordfish as far as 2,000 metres. "There's good evidence for some species and situations in which diving deep is clearly for foraging," Braun said, "so that supported our expectation. However, we also find several cases where we can pretty definitively say the use of the deep ocean is not for feeding, or if it is it represents a totally different kind of predator-prey interaction or mysterious prey resource."

The evidence also suggests that the twilight zone has been overlooked as a critical habitat for large predator species, the researchers said. Many of the species inhabiting the twilight zone are fished commercially, and steps need to be taken to understand and protect this potentially critical ecosystem. "If it turns out that there is indeed more biomass in the twilight zone than in all current marine capture fisheries combined, then it's possible to imagine a kind of mesopelagic 'gold rush' to catch and use this biomass," Braun said. "There are many 'ifs' in this chain and many issues in making mesopelagic fishing feasible, but it seems that biomass may be important for predators. We really need to better quantify those links between predators and mesopelagic biomass before we can sustainably harvest or use those resources."

The newly discovered water mass, called the Atlantic Equatorial Water, stretches from Brazil to West Africa

PLANET EARTH

A 'missing' blob of water predicted to be in the Atlantic is finally found

WORDS **BEN TURNER**

Scientists have discovered a previously undetected water mass in the middle of the Atlantic Ocean: a gigantic body of water stretching across the Atlantic from the tip of Brazil to the Gulf of Guinea near West Africa. The water mass, named the Atlantic Equatorial Water, forms along the equator as ocean currents mix separate bodies of water to the north and south. Until the Atlantic Equatorial Water's discovery, scientists had spotted waters mixing along the equator in the Pacific and Indian oceans, but never in the Atlantic. "It seemed controversial that the equatorial water mass is present in the Pacific and Indian oceans but missing in the Atlantic Ocean because the equatorial circulation and mixing in all three oceans have common features," said Viktor Zhurbas, a physicist and oceanologist at the Shirshov Institute of Oceanology in Moscow. "The identified new water mass has allowed us to complete, or at least more accurately describe, the phenomenological pattern of basic water masses of the world ocean."

Did you know?

The Atlantic Ocean covers 41,105,000 square miles

Far from being the same everywhere, ocean water is a vast patchwork of interconnected masses and layers, mixed together and split apart again by currents, eddies and changes to temperature and salinity. Water masses are the distinct parts of this motley arrangement; each body of water has a shared geography, formation history and common physical properties, such as density and dissolved isotopes of oxygen, nitrate and phosphate. To distinguish water masses, oceanographers chart the relationship between temperature and salinity across the ocean, two measurements that combine to determine the density of seawater. In 1942 this charting led to the discovery of equatorial waters in the Pacific and Indian oceans. Formed from the mixing of waters to the north and south, both the Indian and Pacific equatorial waters have temperatures and salinities curving along lines of constant density that are easily distinguishable from the surrounding water. Yet no such relationship could be spotted in the Atlantic.

To search for the missing water mass, scientists combed through data collected by the Argo program, an international array of robotic, self-submerging floats scattered across the world's oceans. After analysing the data collected by this floating array, the researchers spotted an unnoticed temperature-salinity curve nestled parallel to the curves marking out the North Atlantic and South Atlantic Central waters to the north and south: the Atlantic Equatorial Water.

"It was easy to confuse the Atlantic Equatorial Water with the South Atlantic Central Water, and in order to distinguish them it was necessary to have a fairly dense network of vertical temperature and salinity profiles covering the entire Atlantic Ocean," Zhurbas said. Now that the water mass has been identified, it will give scientists a better understanding of the ocean's mixing processes, which are vital to the oceans' transport of heat, oxygen and nutrients around the globe.

SPACE

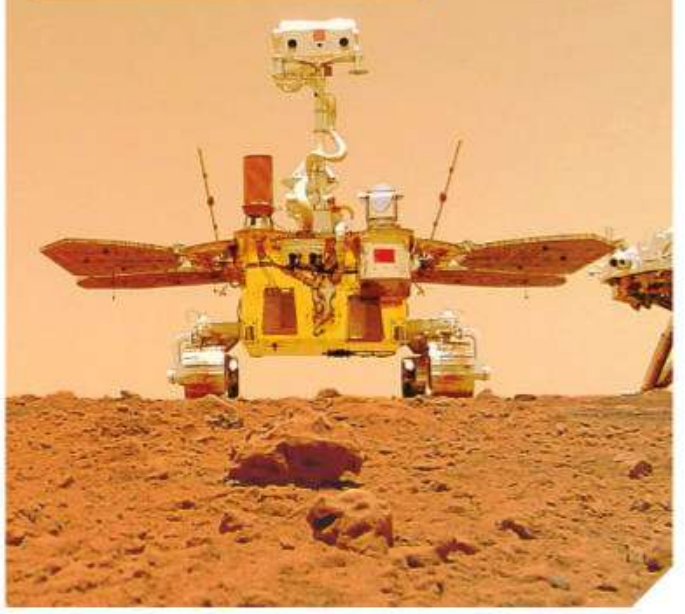
CHINESE SCIENTISTS BUILD A MARS ATMOSPHERE MODEL

WORDS **ANDREW JONES**

Chinese scientists have constructed a numerical model to simulate the Martian atmosphere and assist the country's plans to collect rock samples from the Red Planet. The model replicates the cycles of dust, water and carbon dioxide in Mars' atmosphere. It will be used to simulate meteorological conditions for landing spacecraft, including surface temperature, wind and dust. China plans to launch its Tianwen-3 Mars sample-return mission between 2028 and 2030. A lander will collect up to 500 grams of Martian material using a drill and a robotic arm. An ascent vehicle will then blast the precious cargo back into Mars orbit, to meet up with an awaiting orbiter for the long journey home.

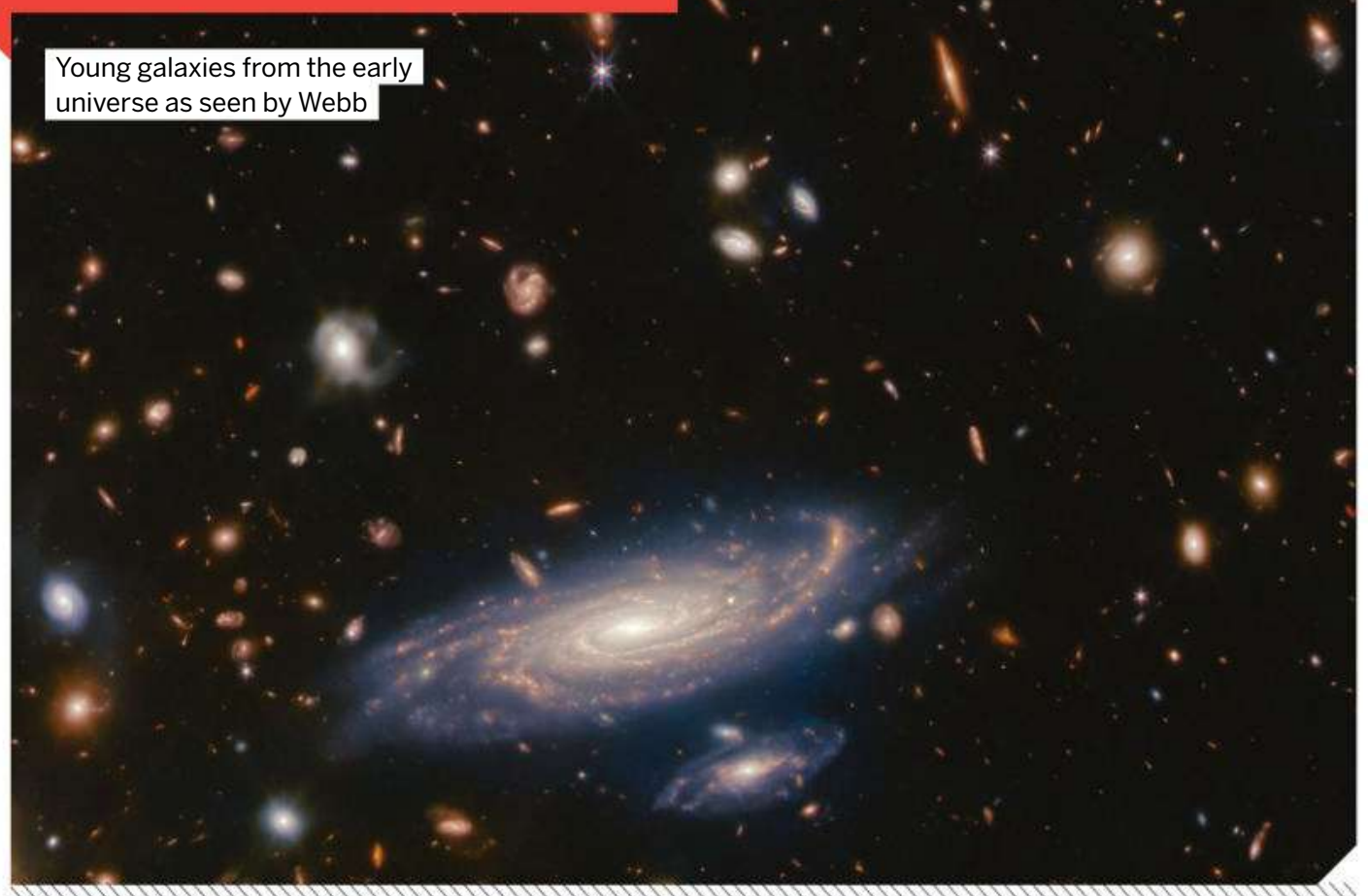
The new atmospheric model "can simulate the temperatures of the landing zone, and scientists can use this data to design materials that are suitable for building Mars rovers to cope with extreme cold," lead researcher Wang Bin said. The model was built using data from China's now-defunct Mars rover Zhurong, NASA's Viking 1 and 2 landers and the OpenMARS reanalysis dataset.

A selfie of China's first-ever Mars rover, Zhurong, and its lander, captured by a deployed remote camera



© Getty / Alamy

GLOBAL EYE



Young galaxies from the early universe as seen by Webb

SPACE

Early ‘teenage’ galaxies contain mysterious heavy elements

WORDS **CONOR FEEHLY**

The deeper we look into space, the further back in time we see. Light emanating from some of the younger galaxies in our universe has to travel for billions of years to reach us, getting picked up by our instruments rich with information from the cosmic dawn. Not only can this light tell us where we have come from, but where we might be headed. To understand the evolution of several of these early universe ‘teenage’ galaxies, a Northwestern University-led team of astrophysicists have inspected data from the James Webb Space Telescope, which gazed back to realms that formed just 2 to 3 billion years after the Big Bang. The observations have thrown up some intriguing surprises.

Specifically, the team analysed results from the Chemical Evolution Constrained using Ionized Lines in Interstellar Aurorae (CECILIA) survey to find that not only do these galaxies appear hotter than expected, they also seem to host heavy elements, like nickel. The researchers focused on 33 distant galaxies for a continuous 30-hour period. They then combined wavelengths of light collected from 23 of those galaxies to create a composite picture of what’s happening in these structures. These light spectra contain clues regarding things like their average temperatures and what elements might be lurking within. “This washes out the details of individual galaxies but gives us a better sense of an average galaxy. It also allows us to see fainter features,” said Allison Strom, an assistant professor of physics and astronomy at Northwestern University.

The composite picture of the galaxies contained eight identifiable elements: hydrogen, helium, nitrogen, oxygen, silicon, sulphur, argon and nickel. While the lighter elements were expected, the presence of nickel, which is heavier than iron in the periodic table, came as somewhat of a surprise. “Never in my wildest dreams did I imagine we would see nickel,” Strom said. Even in older nearby galaxies, nickel rarely is observed, and that’s after multiple life cycles of stars – meaning multiple rounds of supernovae – and the opportunity for heavier elements to synthesise and spread throughout the galaxy. No one ever talks about observing nickel. Elements have to be glowing in gas in order for us to see them, so in order for us to see nickel, there may be something unique about the stars within the galaxies,” Strom said.

Strom believes that the higher observed temperatures in these early galaxies might be connected to their curious chemical composition somehow. “Ultimately, the fact that we see a higher characteristic temperature is just another manifestation of their different chemical DNA because the temperature and chemistry of gas in galaxies are intrinsically linked.”

Did you know?

There are around 100 billion galaxies in the observable universe

HISTORY

2,800-YEAR-OLD IVORY CARVED WITH A SPHINX IS DISCOVERED IN TURKEY

WORDS **TOM METCALFE**

Archaeologists have unearthed an ornately carved elephant tusk in what may have once been an Iron Age centre of power. The ivory carving features a mythical sphinx, a human head on the body of a winged lion, as well as a depiction of a real lion and two tall plants that may represent the mythical tree of life. While the artwork dates to the Iron Age, it was found in an archaeological layer over a much older city, the deserted Bronze Age Hittite capital of Hattusa.

The artefact shows that the Iron Age settlement at the site was an important place, although it was established after the Hittites had abandoned the city in about 1200 BCE during what’s known as the Late Bronze Age collapse. The artefact is about 30 centimetres long and ten centimetres wide, and may have been part of a piece of furniture. After scientific studies of the ivory carving are complete, it will go on display at the Boğazköy Museum.

Archaeologists estimate that the carved piece of elephant’s tusk is about 2,800 years old

Student of Games can master both information-perfect games like Go and information-imperfect games like Scotland Yard

TECHNOLOGY

AI that can master different types of games is built

WORDS **KEUMARS AFIFI-SABET**

Researchers have built the first general-purpose artificial intelligence (AI) algorithm that can master a wide variety of games, dubbed 'Student of Games'. Game algorithms are normally designed to master either information-perfect games like Go or chess, in which each player has all the information, or information-imperfect games like poker, in which some information is hidden from other players. This is because the process of training the algorithms has historically been different for the two types of games. The former uses search and learning, while the latter uses game-theoretic reasoning and learning. But the new Student of Games algorithm gets around this limitation by combining guided search, self-play learning and game-theoretic reasoning.

When tested, Student of Games held its own in both the information-perfect chess and Go, as well as the information-imperfect Texas hold 'em and Scotland Yard. However, it couldn't quite beat the best specialised AI algorithms in head-to-head matchups. "This is a step towards making even more general algorithms," said Martin Schmid, CEO and cofounder of EquiLibre Technologies. "One takeaway is that you can indeed design a technique that can work for both perfect and imperfect information games, rather than having specialised algorithms. Another interesting observation was that one of the important steps was to come up with a new formalism, allowing for truly general design of search based algorithms."

Games have long served as a benchmark for progress in the field of AI. In 2016, DeepMind's AlphaGo beat a professional human Go player. The next year, the Libratus system beat the world's best human poker players in a 20-day Texas hold 'em tournament. "Games are a well-defined benchmark, and there is a long history of AI progress being tied to milestones in AI for games," Schmid explained. "Games are sometimes referred to as fruit flies of AI, allowing for quick development and gradual progress."

But there has always been a divide between information-perfect and imperfect games. To get around this, the team trained its general-purpose algorithm using what's known as a growing-tree counterfactual regret minimisation algorithm, a variation of a widely used algorithm in which an AI system learns by playing against itself repeatedly. The team combined techniques used to build a variety of game-playing algorithms, from AlphaZero – a more advanced version of AlphaGo – to DeepStack, the first computer program to outplay human professionals in Texas hold 'em poker. In the information-perfect category, the team found that Student of Games performed as well as human experts or professionals, but it was substantially weaker in head-to-head play than specialised algorithms like AlphaZero. It did, however, beat the Texas hold 'em algorithm Slumbot, which the researchers claim is the best openly available poker agent, while also besting an unnamed state-of-the-art agent in Scotland Yard.

However, Student of Games would fall flat in complex games in which there's much more hidden information kept from participating players than in poker. For example, in no-limits hold' em there are 1,326 possible opening hand combinations players may encounter. "Games like *StarCraft* or Stratego, which both have a much, much bigger list of possible private information that each player could have, would be infeasible for Student of Games to play," said Finbarr Timbers, a researcher at Midjourney. In the future, the researchers plan to explore limitations they encountered, particularly how to reduce the high costs and computational power involved in running Student of Games and achieving strong performance.

© NASA; ESA; JWST / Getty

ANIMALS

CRABS EVOLVE TO GO FROM THE SEA, TO THE LAND AND BACK AGAIN

WORDS **CARYS MATTHEWS**

Crabs have evolved to migrate from the sea to land then back again multiple times over the last 100 million years. In a new study, researchers found that true crabs, which consist of 7,600 species across 109 families, have evolved to migrate from marine to land habitats between 7 and 17 times. They also found that on two or three occasions, crabs even went back to the sea from land. Researchers set out to discover how often and when true crabs left the marine environment for land. They compiled three new datasets for 333 species of true crabs from 88 families, including both marine and non-marine groups.

Using the entire crab fossil record, the researchers applied two mapping pathways: one where the crab goes from a fully marine environment to land directly through intertidal zones such as beaches, and a second where the species migrates from fully marine to land indirectly, through estuaries, fresh water, riverbanks, coastal forests and jungles. Their findings suggest that true crabs emerged about 45 million years earlier than previous estimates and could date back to the mid-Triassic period, making them as old as some of the earliest known dinosaurs.

The Christmas Island red crab is a species of true crab that lives on land

PLANET EARTH

Supervolcano 'megabeds' point to catastrophic events in Europe every 15,000 years

WORDS **HANNAH OSBORNE**

Huge 'megabeds' from ancient supervolcano eruptions are hiding at the bottom of the Mediterranean Sea. Their discovery points to a cycle of catastrophic events that appear to hit the region every 10,000 to 15,000 years. Megabeds are huge sub-marine deposits that form in marine basins as a result of catastrophic events like volcanic eruptions. The researchers found the beds while investigating deposits at the bottom of the Tyrrhenian Sea, near the coast of Italy, close to a large underwater volcano. Previous research into geohazards in the area using sediment cores and imaging indicated something was hidden beneath the ocean, but the resolution was not high enough to see the megabeds.

In a new study, Derek Sawyer, associate professor of Earth sciences at Ohio State University, and colleagues went back to the site to create higher resolution images of the layers of sediment, discovering a succession of four megabeds, each between 10 and 25 metres thick and each separated by distinct layers of sediments. Cores drilled from the site showed the megabeds were made of volcanic material. The oldest layer was around 40,000 years old, the next oldest was 32,000 years, the third 18,000 years, while the youngest formed about 8,000 years ago.

The team then looked at known volcanic activity in the region to determine the source of the megabeds. The region where the beds formed is extremely active volcanically and includes the Campi Flegrei supervolcano, which has been rumbling recently. The oldest megabed formed after a huge eruption from Campi Flegrei 39,000 years ago, one of the biggest known eruptions on Earth. The same eruption may also have created the second bed, as the layer between the two is just one metre, indicating a relatively short interval between the two events. The scientists think that the 18,000-year-old megabed formed in the wake of the Neapolitan Yellow Tuff supereruption of Campi Flegrei about 15,000 years ago, while the youngest megabed was deposited by another less energetic eruption at Campi Flegrei.

The eruptions occurred roughly every 10,000 to 15,000 years. However, they are refining the eruption dates to get a more precise picture of the cycle and potential risk for the future. "It's not as constrained as we would like it to be," Sawyer said. The findings will help researchers understand the risk posed by volcanoes in the region. "That whole field is still active; there's still a lot of concern about the future of that, so it's certainly potentially possible that it could happen again."

Scientists have discovered 'megabeds' at the bottom of the ocean that appear to have been formed by ancient supervolcano eruptions

African elephants in Amboseli National Park, Kenya, appear to have names for each other

ANIMALS

Elephants give each other names

WORDS **RICHARD PALLARDY**

Can you name a famous elephant? Babar, perhaps? Or Dumbo? Memorable though these monikers may be to humans, they sound nothing like the names elephants give each other. If you're an elephant, your name is something more like a low, rumbling sound, scientists say. Researchers have found that African savannah elephants make vocalisations specific to individuals in their social groups, and that the recipients responded accordingly. In short, elephants appear to have names for one another. This makes them the first non-human animals to address each other in a manner that does not imitate the receiver's own call, as dolphins and parrots do. And while other animals do produce what are known as 'referential calls' in order to identify objects such as predators or food, those calls are believed to be instinctive and do not require social learning.

Scientists recorded 527 elephant calls in the greater Samburu ecosystem in northern Kenya and 98 calls in Amboseli National Park in southern Kenya. The researchers then identified rumbles specific to 119 individuals by discerning which members of the groups of female elephants and their offspring were separated from the herd at the time of each vocalisation or approached when the call was made. Using a computer model, researchers correctly identified the receivers of 20.3 per cent of the 625 recorded calls. This marks a step forward in understanding how these highly intelligent animals communicate. "There's a contact rumble, there's an anti-predator rumble, there's a greeting rumble. If you look at a spectrogram, they all look almost exactly the same," said Caitlin O'Connell-Rodwell, an elephant biologist at Harvard University Medical School. "That's why AI has been exciting. It allows us to really figure out what the elephants are honing in on."

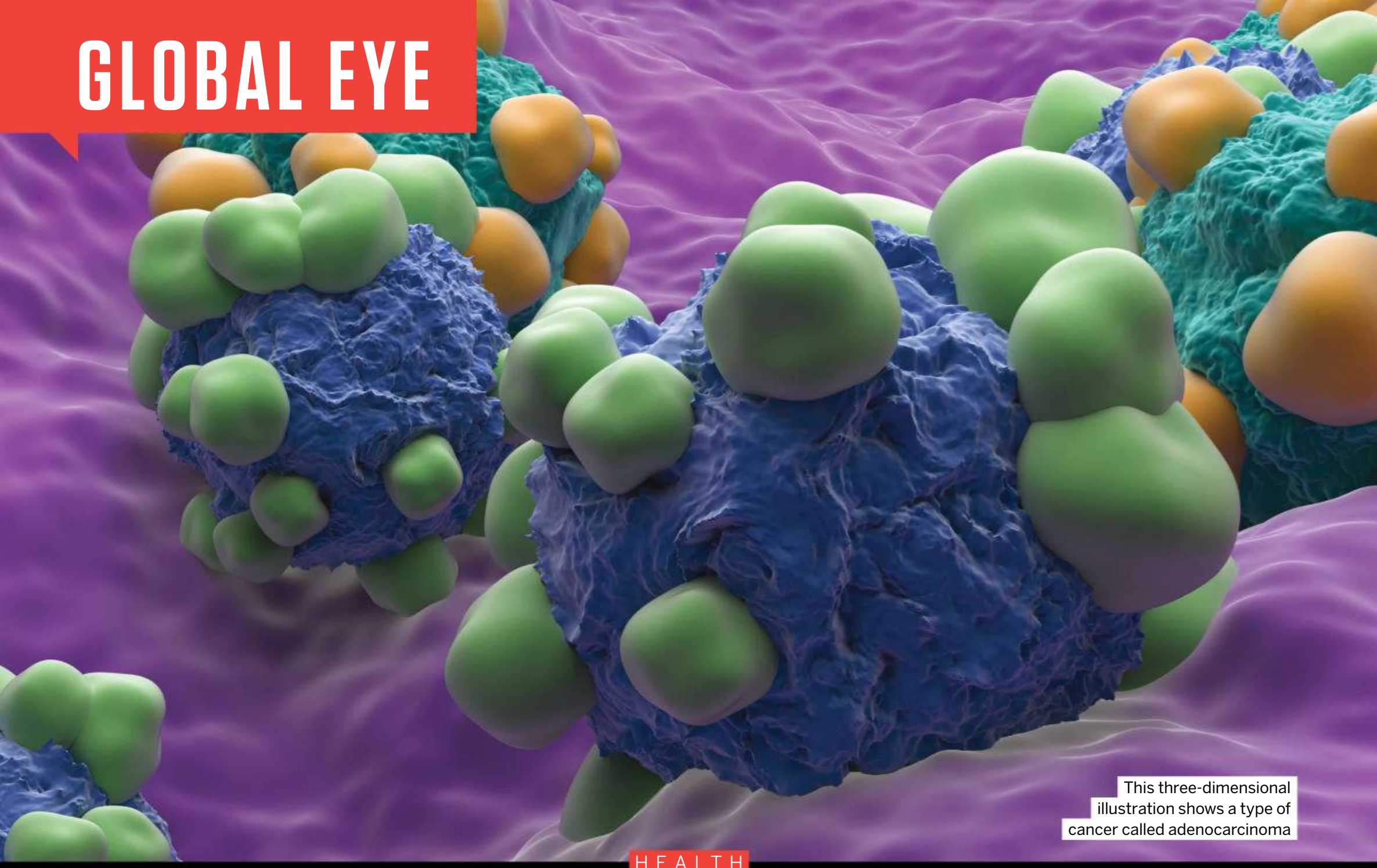
As it turned out, the calls were not generic sounds aimed at, for example, younger elephants or mothers. They were distinct to the receiver. Even calls from different callers to the same receiver were similar, though the pattern was less obvious than it was between a single caller and receiver. This may be because rumbles encode multiple messages simultaneously, so the computer model may not have been able to pick out the 'name' used in each call. "It just highlights the complexity of what's going on," O'Connell-Rodwell said. "And we're not skilled enough at what those measurements should be to figure out what's going on."

Did you know?

An elephant herd can consist of up to 100 individuals

The researchers also found that elephants responded more strongly to recordings of calls originally addressed to them than to calls addressed to other elephants, further supporting their findings. "The real value of this paper is that it shows how elephants are navigating through a large landscape and can still keep in touch with specific individuals. It allows them to spread out much further and still have very close tabs on individuals, not just the group. It's not just like, 'I'm sending out a ping'. Somebody else is sending out a ping. It's much more sophisticated than that."

© Getty



This three-dimensional illustration shows a type of cancer called adenocarcinoma

HEALTH

Healthy tissue may predict lung cancer's return better than tumours

WORDS **EMILY COOKE**

It may be possible to predict whether a person's lung cancer could return after surgery by zooming in on the seemingly healthy tissue near their tumours. Lung cancer is the leading cause of cancer deaths in the US. One of the most common types is lung adenocarcinoma, which arises in the cells that line the air sacs of the lungs. The usual treatment for the early stages of this disease, before the cancer has spread, is surgery to remove the tumour. However, even when caught at this early stage, cancers like adenocarcinoma return 30 per cent of the time, and so far there has been no accurate way to predict whether this will occur.

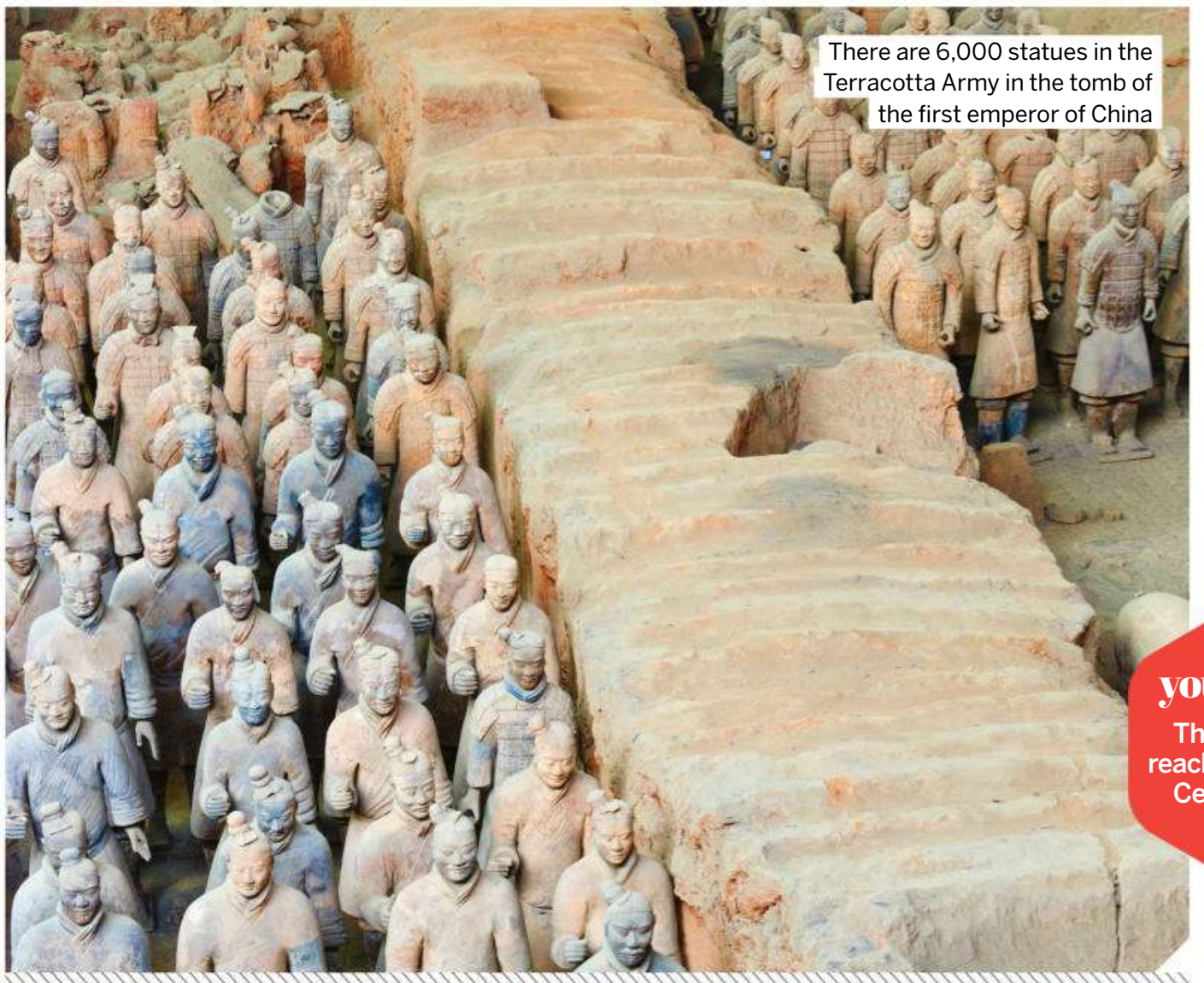
Scientists analysed tissue samples from 143 men and women with early stage lung adenocarcinoma. They found that the activity of genes, specifically those involved in inflammation, in the healthy lung tissue adjacent to tumour cells was able to more accurately indicate whether a patient's cancer returned within five years of surgery than the corresponding gene expression in tumour cells. The new research was conducted only in the laboratory in isolated tissue samples. However, the researchers hope the findings could eventually be used to flag patients at high risk of relapse and ensure that they receive additional care.

"If you determine that the patient is at high risk then you can do two things: monitor them more frequently, or even – but this of course requires a clinical trial – think of potential therapies in addition to surgery," said Aristotelis Tsirigos, a cancer biologist at New York University Langone Health. For instance, some immunotherapies, which help the body's cells detect and attack tumours, are already being trialled in early stage lung cancer.

Scientists focused on the transcriptome, meaning all the RNA molecules in the tissues they sampled. RNA shuttles instructions for how to build proteins from a cell's DNA to its protein-making factories. In addition, the team gathered information on whether a patient's disease returned after surgery to retrospectively predict their risk of recurrence using artificial intelligence. Overall, they found that analysing RNA from healthy lung tissue accurately predicted cancer recurrence 83 per cent of the time, compared with 63 per cent for tumour cell RNA.

The authors also discovered that the RNA for inflammatory proteins, such as tumour necrosis factor-alpha and interferon-gamma, were the strongest predictors of recurrence. In a separate part of the study, the authors found that the same group of inflammatory proteins were also associated with poorer outcomes for patients with other types of cancer, such as breast and kidney cancer. They deduced this using data from the Cancer Genome Atlas, a collection of cancer tissue samples collected from more than 11,000 patients in the US over 12 years.

Before this research can be tested in clinical trials, further studies are needed to understand exactly what activates these inflammatory genes in healthy tissue and how this can forecast recurrence.



There are 6,000 statues in the Terracotta Army in the tomb of the first emperor of China

HISTORY

Remains of a 2,000-year-old sheep-drawn chariot discovered

WORDS **TOM METCALFE**

Archaeologists have discovered the remains of what appears to be an ancient sheep-drawn chariot near the famous Terracotta Army in northwestern China. The remains were found in the 'western tomb' at the site of Emperor Qin Shi Huang's mausoleum, a few miles northeast of the city of Xi'an in Shaanxi province. The main structure of the chariot has likely rotted away after spending more than 2,000 years in the ground – the mausoleum dates to the third century BCE – but researchers did find a row of six sheep skeletons wearing accessories used for pulling a chariot, so they inferred this was a sheep-drawn chariot.

Horse-drawn chariots and ox-drawn carts were common in ancient China, but a sheep-drawn chariot is an extremely rare find. They appear in Chinese history, however, as well as in Chinese lore. The founder of the Western Jin dynasty, Emperor Wu, or Sima Yan, who ruled from 266 to 290 CE, is said to have ridden in a sheep-drawn carriage around his palace complex every night and would sleep wherever the sheep stopped. His practice may be the origin of the modern Chinese phrase 'seeking luck in a sheep cart'. It's said that the emperor had a harem of 10,000 wives, and this seems to have been Sima Yan's method of choosing among them. Researchers hope laboratory analysis on the western tomb's burial chamber, which is currently underway, will help them determine who was buried there.

In addition to the six-sheep chariot, archaeologists unearthed a four-wheeled wooden chariot, presumably drawn by horses, equipped with an ornate rectangular umbrella. It is the oldest of its type ever found. They also found a wealth of copper chariot and horse-related artefacts, as well as iron tools and copper weapons, providing new insight into the period when iron tools first began to appear.

The mausoleum of Emperor Qin Shi Huang, who ruled from 221 to 210 BCE and is considered to be the first emperor of a united China, is spread over about ten square miles and took 38 years to complete. Three immense pits in the mausoleum site hold more than 8,000 life-sized sculptures that depict the emperor's soldiers and their horses, the so-called Terracotta Army.

SPACE

HYDROGEN FOUND IN MOON ROCKS

WORDS **SHARMILA KUTHUNUR**

A fresh analysis of Moon rocks brought home during the Apollo missions has revealed the presence of hydrogen. This suggests future astronauts could use water available right on the Moon for life support and rocket fuel. Researchers with the US Naval Research Laboratory (NRL), to whom NASA provided the lunar samples, have announced they discovered hydrogen in lunar soil sample 79221.

"Hydrogen has the potential to be a resource that can be used directly on the lunar surface when there are more regular or permanent installations there," said Katherine Burgess, a geologist at NRL. "Locating resources and understanding how to collect them prior to getting to the Moon is going to be incredibly valuable for space exploration."

Per one NASA estimate, it would cost thousands of dollars to launch a bottle of water to the Moon. To cut costs, ice on the Moon can be used in-situ as water for astronauts, and may also be broken down into its hydrogen and oxygen components to be used as rocket fuel for journeys between the Moon and Earth. Perhaps it can be used to bring humans to Mars as well someday.

Did you know?

The Moon can reach 120 degrees Celsius during the day

Apollo 17 samples reveal it might be possible for future astronauts to harvest water available on the Moon to use as rocket propellant

© Getty / NASA; Johnson Space Center

WISH LIST

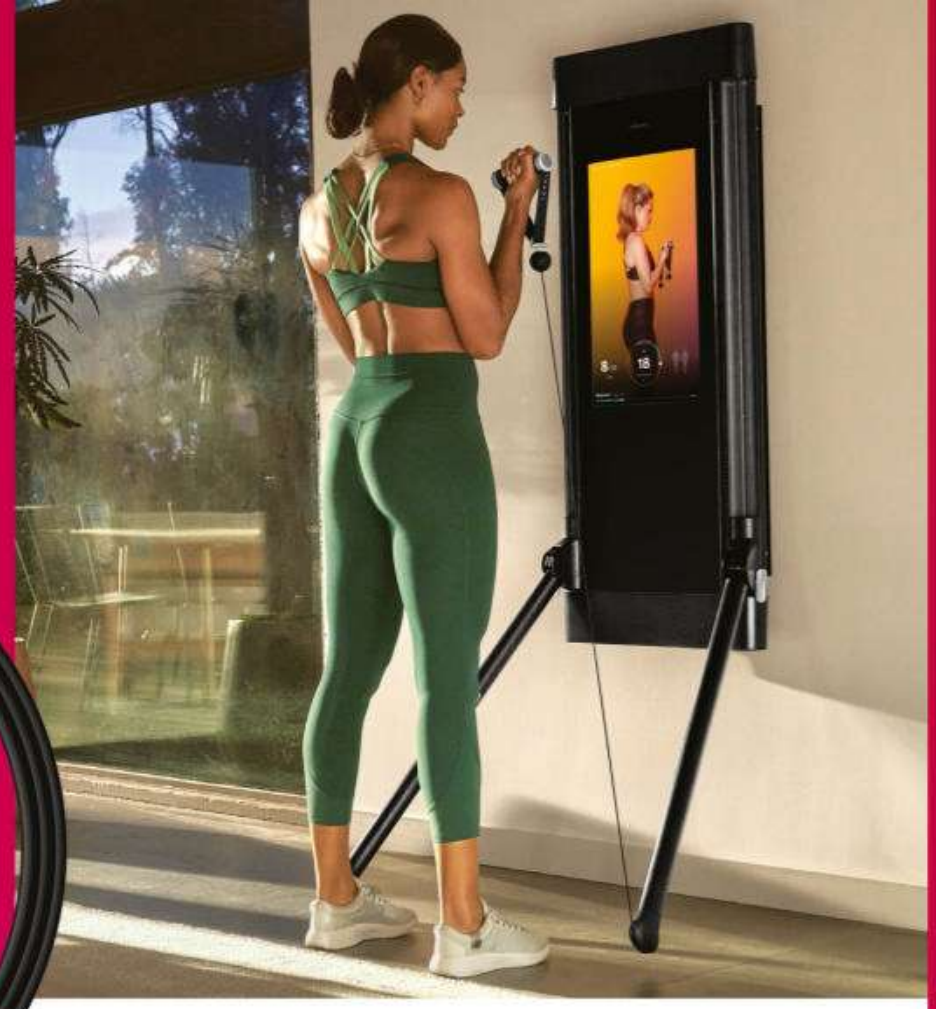
The latest HEALTH AND FITNESS tech

SMARTROPE PURE

£60 / $64.95

TANGRAMFACTORY.COM

The SmartRope PURE allows you to keep track of your jump rope workouts using its built-in magnetic sensors. Paired with your smartphone, you will be able to track not only the basic skip counts but also undergo interval training, compare global leaderboards and set challenges with your SmartRope-using friends. It also has the bonus of built-in memory, so you can save up to 100 sets of workouts and records before you need to sync the data with your smartphone. The SmartRope PURE has a battery life of up to 45 hours of active training after a two-hour charge.



TONAL

$3,995 (APPROX. £3,160) **TONAL.COM**

If you're looking to reap the benefits of having a full home gym but don't have the space for a lot of equipment or just want your workout focused in one place, then Tonal might be for you. Packed with countless workouts to discover, including strength training, cardio, yoga and pilates, Tonal has pretty much everything you could want from a home gym. After an evaluation of your strength and abilities, you can navigate through workouts with a virtual coach and track your progress as you go. Tonal is also fully integrated with several other apps, including Apple Health, Strava and Amazon Music.

FORM SMART SWIM GOGGLES

£249 / $249 **FORMSWIM.COM**

Getting real-time performance stats while you're in the water is near impossible – that is unless you have a pair of FORM's augmented-reality swimming goggles. From a swimmer's heart rate to the distance between their strokes, these goggles can let the wearer know a whole host of information about their form as they are swimming. As well as real-time feedback, the built-in visual coach can help you evolve your swim technique and provides more than 1,500 workouts. These goggles aren't solely for swimming in pools, also capable of offering metrics on pace, time and distance while you're out in open water. Some metrics, however, such as stroke count, are currently unavailable outside of pool use.

HYDROW ROWER

£1,995 / $2,495 HYDROW.COM

The humble rowing machine has been given a high-tech immersive update in the form of the Hydrow Rower. To help you through your rowing session, the Hydrow comes with a 22-inch touchscreen display programmed with more than 4,000 workouts. There's an option to select from over 100 scenic destinations to row through, and as well as providing the typical rowing stats such as speed and distance, the Hydrow can connect via Bluetooth to an Apple Watch to show data such as heart rate on its display. You can also track your workout metrics, climb up the live leaderboard with other rowers and earn Hydrow achievement badges when you meet your milestones.

WAHOO CYCLING SENSORS

£29.99 / $39.99 WAHOOFITNESS.COM

If you're a keen outdoor cyclist and want to watch your speed, you might want to consider fitting your bicycle with a wahoo speed or cadence sensor. Bluetooth compatible, these magnet-less sensors wirelessly connect to your smartphone from the bike's front wheel hub to record and send information straight to your favourite cycling app or a bike's GPS computer. Both sensors use coin cell batteries that have a battery life of up to a year and are waterproof up to 1.5 metres.

PUREMAX 4D

FROM £129 (APPROX. $160) WAATR.CO.UK

Stay hydrated and healthy during your workouts with the PureMax 4D water bottle. Using '4D Purification technology', ultraviolet-C LEDs are beamed onto the enclosed water to destroy 99.99 per cent of biocontaminants. Then the water is passed through one of three filter types to reduce metals, chemicals and organic matter in the water before using a blend of minerals to improve its flavour. The PureMax 4D comes in three different sizes up to 1,200 millilitres, six different colours and boasts triple insulation to keep drinks cold for 24 hours.

© Hydrow / FORM / Tangram / Tonal / Wahoo / Waatr

AMAZING SUBSCRIPTION OFFER!

SUBSCRIBE & SAVE 50%

WHY WE'RE MADE OF STARDUST
HOW IT WORKS
VR BATTLEFIELD TRAINING
DISCOVER YOUR SIXTH SENSE
DO YOU PERCEIVE THE WORLD AROUND YOU IN WAYS OTHER PEOPLE CAN'T?
12 SECRET UNDERGROUND STRUCTURES
WHY THIS PLANT CHANGED LIFE ON EARTH
HOW PACIFIC ISLANDERS CONQUERED THE OCEAN
SEEING INVISIBLE COLOURS
SPIDER SENSES
SUPER SMELLER
GAZE DETECTION
WHAT MAKES CHOCOLATE SO ADDICTIVE?
+ WHAT IS SEA FOAM? / SOUNDPROOFING SCIENCE / HOW HADRIAN'S WALL WAS BUILT / DO COWS HAVE FOUR STOMACHS?
DO VITAMIN PILLS WO
MINEFIELD DETECTION DEVICES EXPLAINED
WHY THIS CONTROLS YOUR LIFE
HOW THE "MASTER GLAND" DECIDES WHEN YO
HUNGRY, HAPPY AND EVEN HOW BIG YOU GRO
+ WHAT IS ALZHEIMER'S? / HOW HENNA ST
CHAT EXPLAINED
WHAT ASTRONAUTS DO ON THE ISS
LOCH NESS LEGEND
ES
FOOT
EXIST?
ER MYTHS BUSTED
BY SCIENCE
KRAKEN FINALLY FOUND
HOW SUGARY SWEETS AFFECT YOUR BODY
ALL ABOARD THIS POSH HYDROFOIL BOAT

SPECIAL
WHY WE'RE MADE OF STARDUST
HOW IT WORKS
VR BATTLEFIELD TRAINING
DISCOVER YOUR SIXTH SENSE
DO YOU PERCEIVE THE WORLD AROUND YOU IN WAYS OTHER PEOPLE CAN'T?
12 SECRET UNDERGROUND STRUCTURES
WHY THIS PLANT CHANGED LIFE ON EARTH
HOW PACIFIC ISLANDERS CONQUERED THE OCEAN
SEEING INVISIBLE COLOURS
SPIDER SENSES
SUPER SMELLER
GAZE DETECTION
WHAT MAKES CHOCOLATE SO ADDICTIVE?
WHAT IS SEA FOAM? | SOUNDPROOFING SCIENCE | HOW HADRIAN'S WALL WAS BUILT | DO COWS HAVE FOUR STOMACHS?

Subscriber benefits

- Brilliant value: pay £18.68 for six months
- Every issue delivered directly to your door
- Never miss an issue

SUBSCRIBE NOW

www.magazinesdirect.com/HIW185

OR CALL 0330 333 1133 & QUOTE C73V

***Terms and conditions:** Offer closes 2 February 2024. Offer open to new UK subscribers only. Direct Debit offer is available to UK subscribers only. Pay only £18.68 every six months, saving 50 per cent on the cover price. Savings are based on the annual subscription rate. We will notify you in advance of any price changes. Please allow up to six weeks for delivery of your first subscription issue, or up to eight weeks overseas. For full terms and conditions, visit **www.magazinesdirect.com** terms. For enquiries please call: +44 (0) 330 333 1113. Lines are open Monday to Friday 08:30 to 19:00 and Saturday 10:00 to 15:00 UK time (excluding Bank Holidays) or email **help@magazinesdirect.com**. Calls to 0330 numbers will be charged at no more than a national landline call, and may be included in your phone provider's call bundle.

DID YOU KNOW? Greek philosopher Aristotle was first to number the senses in around 350 BCE

DISCOVER YOUR SIXTH SENSE

WORDS SCOTT DUTFIELD

Uncover the science behind your five senses – plus others that you may not know you have

Senses have been around for billions of years, ever since prehistoric bacteria began interacting with their environment. The first sense on the scene was likely taste – a way for bacteria to detect nearby nutrients some 2 billion years ago. However, it wasn't until around 500 million years ago that vertebrates first developed taste. Similarly, bacteria were the first to develop light sensitivity before the first eyes emerged around 541 million years ago among a now-extinct group of marine creatures called trilobites. Since then, humans and animals have evolved to carry around a sensory toolbox to witness and interpret the world around us.

The human body is packed with different kinds of senses that can be grouped into the five classic senses: touch, taste, sight, smell and hearing. Each one supplies our brains with vital information about our environment so that it can construct an overview of the world and our interactions with it. As we age, these senses change and adapt. For example, as the years go by taste buds increasingly lose their flavour-detecting skills and the nerves that alert us to the feeling of extreme temperatures find it more difficult to alert us to these changes. The brain is also able to make adjustments to the sensitivity of some senses when one or more senses are lost, known as neuroplasticity. And there are super sensors among us – people whose senses are naturally enhanced, allowing them to taste more flavours, see more colours and smell more scents.

Did you know?

35 per cent of adults have 20/20 vision

© Getty

THE SCIENCE OF SIGHT

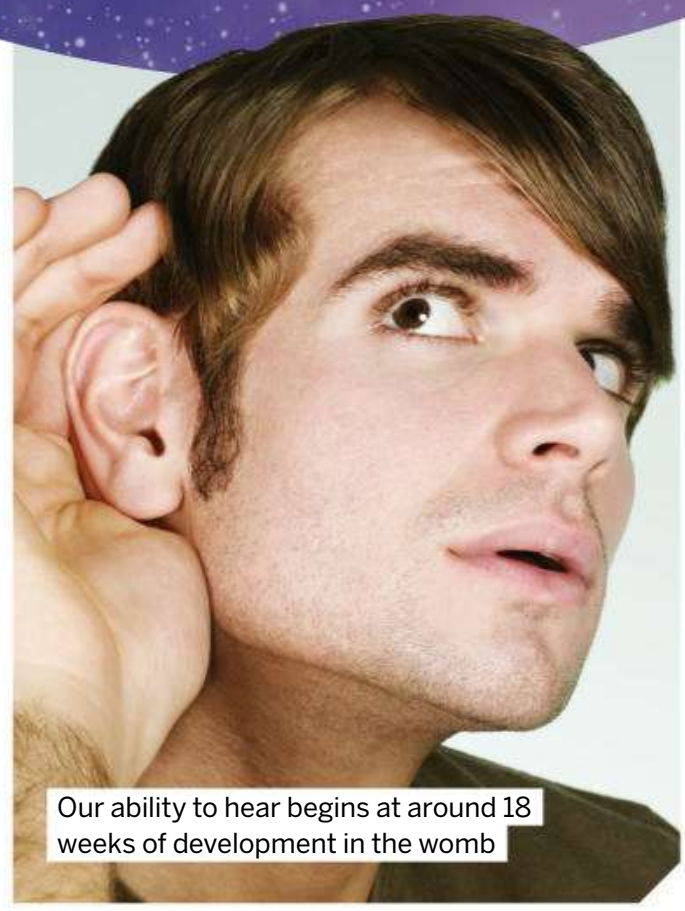
The ability to see comes from a collaboration of optical lenses and specialised cells called photoreceptors. When light bounces off the objects around you, it hits your eyes through a lens called the cornea and passes an opening called the pupil, the size of which is controlled by the coloured portion of the eye, called the iris. The light then reaches the back of the eyes, where groups of photoreceptors make up a layer of tissue called the retina. These cells play an integral role in understanding not only the size and shape of objects, but also their colour. When different wavelengths of light hit your retinae they activate different photoreceptor cells, known as cones, of which the eye has millions. There are three types of cone cells: blue cones, green cones and red cones. Each is responsible for detecting a specific wavelength of light, and when all three work together, they can detect a spectrum of colours. When all the cones are equally stimulated by light, the brain perceives the colour in front of it as white.

Rod cells, another kind of photoreceptor, are also found in the retinae and record light levels and the size and shape of objects. When these photoreceptors are stimulated by light, they generate an electrical impulse that travels along a connecting optic nerve to the visual cortex of the brain to be deciphered into an image.

It's estimated that 300 million people in the world are colour blind

SUPER SENSE

Rather than the standard three cone cell types in the retinae, people with a colour super sense called tetrachromacy have four types. Tetrachromacy gives people the ability to see the world in around 100 times more colours and shades than the average person. The condition is the result of a genetic mutation within the X chromosome, making women more likely to develop tetrachromacy because of their two X chromosomes, as opposed to men who have an X and a Y chromosome.



Our ability to hear begins at around 18 weeks of development in the womb

HOW WE HEAR

Our perception of sound comes from two handy organs sitting neatly on either side of our heads. As sound waves move into the ear canal and arrive at the eardrum, they vibrate it. The eardrum is a thin membrane that carries these vibrations around three tiny bones known as the middle ear before they are amplified by a snail-shaped structure called the cochlea. Fluid within the cochlea ripples with every vibration, triggering hair-like cells within that detect the different pitches in the vibrations and generate an electrical signal along the neighbouring auditory nerve. The auditory nerve delivers the signal to the brain, where it is interpreted as sound along with its many aspects, such as its volume, pitch and tone. A typical human ear can hear sound waves in the frequency range of 20 to 20,000 hertz, but the physiology of the human auditory system means we are unable to perceive sounds outside of this range.

SUPER SENSE

While the world is missing a set of super-hearing humans that can pick up ultrasonic sound waves or a pin falling miles away, one in 50,000 people have a condition that gives them an increased sensitivity to sound. Known as hyperacusis, this rare condition makes everyday sounds seem extremely loud and is often caused by damage to the eardrum or as the result of autoimmune diseases such as lupus erythematosus. The brains of sufferers over-interpret the volume of the same sound waves heard by a typical ear, causing discomfort and heightened sound sensitivity.

Did you know?

Human eyes have over 100 million rod cells

"When all the cones are equally stimulated by light, the brain perceives the colour in front of it as white"

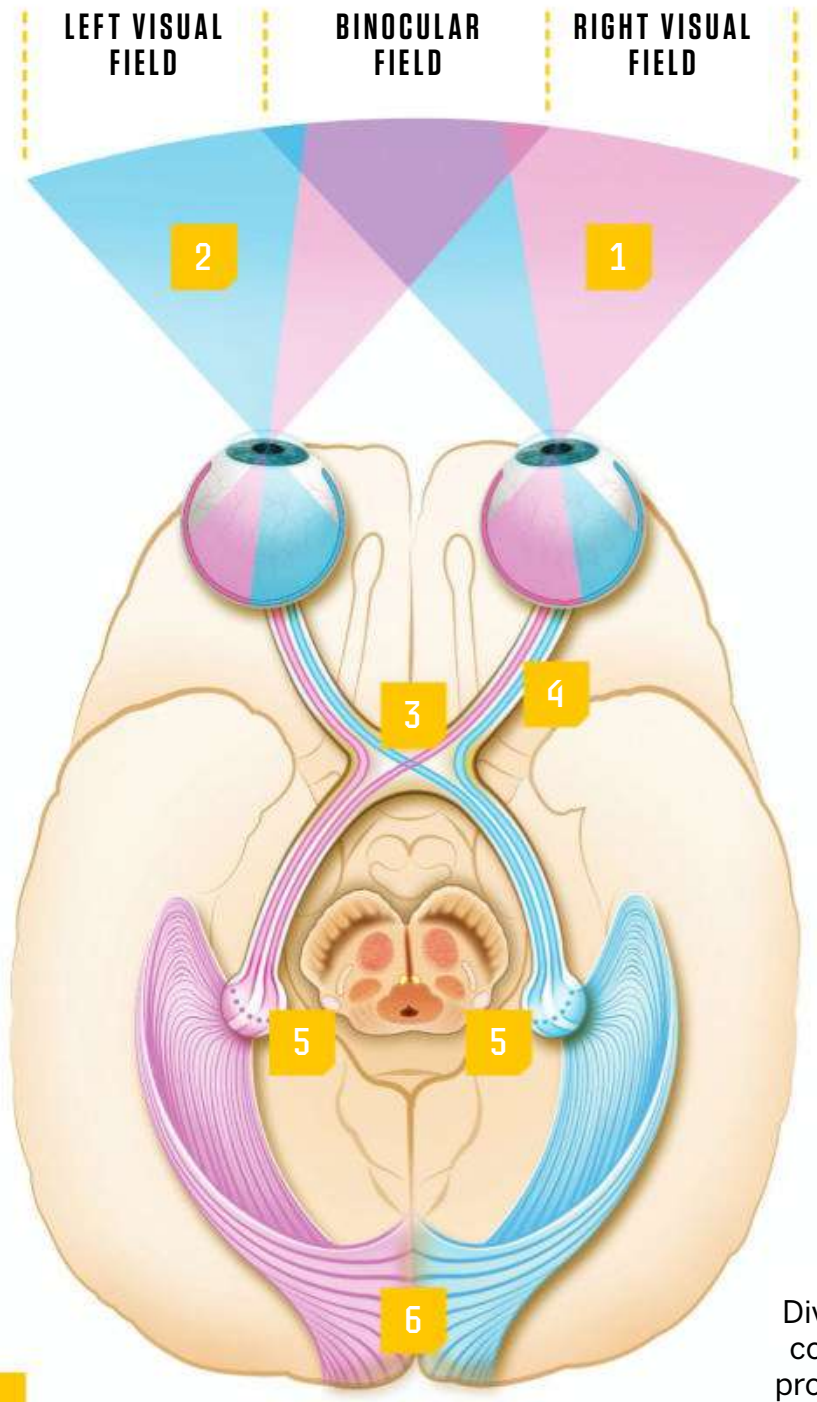
DID YOU KNOW? The loudest sound ever recorded was the 310-decibel Krakatoa eruption in 1883

WHEN SENSES CROSS

What happens when the pathways of sight, sound or taste intermingle and are experienced simultaneously? Known as synesthesia, this phenomenon occurs when senses overlap and is often described as crossed-wire connections within the brain. There are several different forms of synesthesia, such as seeing the colour of sounds or tasting the flavour of words. It's believed that this fascinating phenomenon may form during the brain's early development when there are more neuron cell connections within the brain. Its occurrence may also be genetic, with many people with synesthesia sharing the strange sensations with family members. The phenomenon may also occur later on in life after experiencing damage to the brain or following the use of certain recreational drugs called psychedelics.

SENSORY PATHWAYS

How sight and sound find their way through the human brain



SIGHT

1 RIGHT EYE
The vision in your right field of view is interpreted by the left side of your brain.

2 LEFT EYE
The vision in your left field of view is interpreted by the right side of your brain.

3 OPTIC CHIASM
The site where the optic nerve crosses, found in front of the hypothalamus.

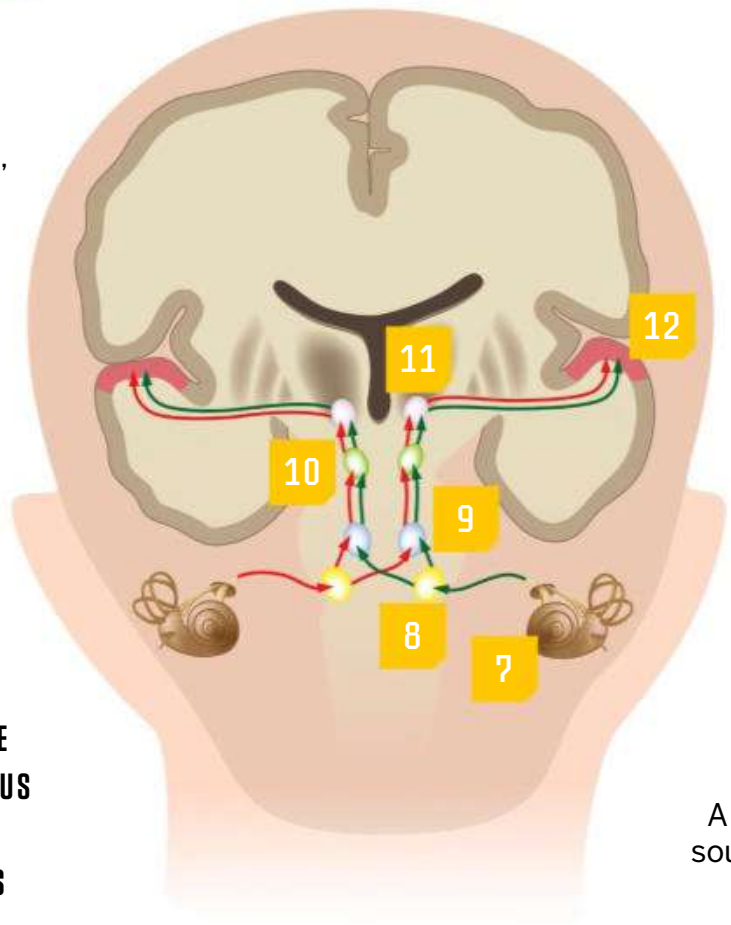
4 OPTIC NERVE
The signal generated by the retinae travels along the optic nerve, which is made up of millions of nerve fibres.

5 LATERAL GENICULATE NUCLEUS
Both eyes supply this multilayered structure that acts as a gateway to the cerebral cortex.

6 PRIMARY VISUAL CORTEX
The vision-processing plant of the brain, which receives and interprets visual stimuli.

SOUND

12 AUDITORY CORTEX
Divided into three parts, this complex region of the brain processes the auditory signal and interprets its qualities, such as volume and pitch.



10 INFERIOR COLLICULUS
The signal's third stop is the inferior colliculus, a midbrain used for auditory processing.

11 MEDIAL GENICULATE
Found in the thalamus, the medial geniculate directs signals to the correct portions of the brain for interpretation.

9 SUPERIOR OLIVARY COMPLEX
The second stop in the brainstem, the signal passes through this region, which helps locate where sound originates outside of the body.

8 COCHLEAR NUCLEUS
This is where the auditory nerves enter the brainstem.

7 COCHLEAR
A fluid-filled cavity where sound waves are converted into electrical signals.

- MEDIAL GENICULATE
- INFERIOR COLLICULUS
- SUPERIOR OLIVARY
- COCHLEAR NUCLEUS

© Shutterstock / Getty

THE SECRETS OF SMELLING

The cacophony of scents and odours in the world can be detected by a small patch of tissue in the roof of your nasal cavity called the olfactory epithelium. Within this are millions of olfactory sensory cells that patiently await odour chemicals binding to their receptors, triggering an electrical impulse that moves along nerves to a structure in the brain called the olfactory bulb. It's estimated that the average person can smell more than a trillion scents, but for a small number of people, sensitivity to these smells is greatly increased.

Scent receptors in the nose renew every 28 days

3 OLFACTORY BULB
Neural electrical impulses generated within the olfactory epithelium are received by a piece of tissue called the olfactory bulb.
5 OLFACTORY THALAMUS
At the thalamus, the impulse is processed, identified and remembered.
3
5
4
2
1
2 OLFACTORY EPITHELIUM
Smell chemicals reach a layer of packed olfactory cells for detection.
4 PIRIFORM CORTEX
This region of the brain receives the impulses directly from the olfactory bulb before they're processed by the thalamus.
1 ODOURS
Organic volatile compounds or smell chemicals enter the nose through the nostrils and the nasal cavity.

PAST THE NASAL PASSAGE

An odour's journey through the mucus-lined nose to the olfactory epithelium

Did you know?

Smell accounts for 80 to 85 per cent of flavour

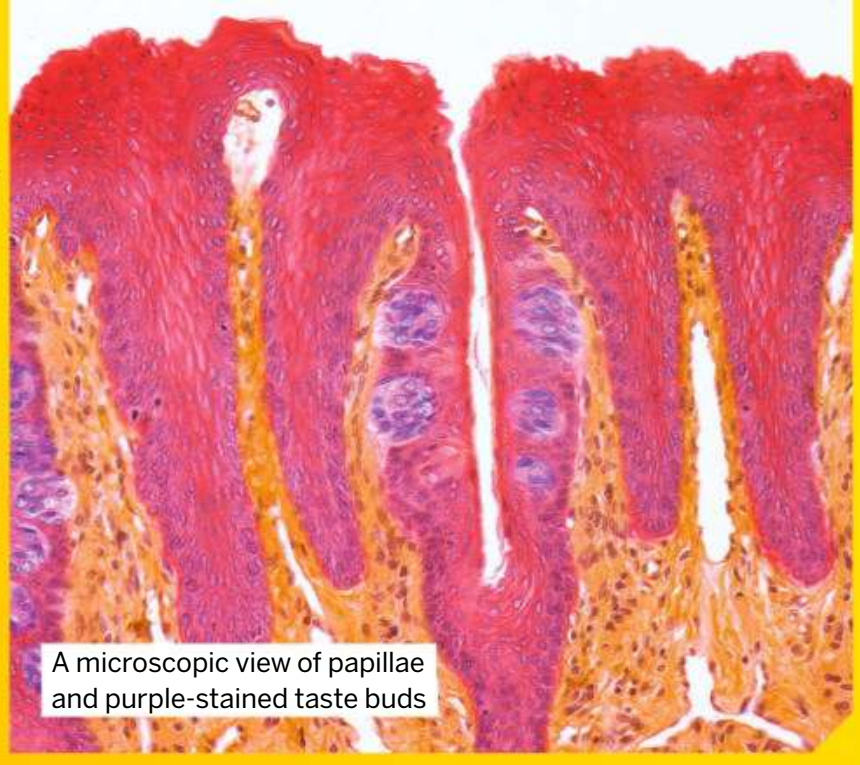
SUPER SENSE

At least three per cent of Americans have increased sensitivity to smells due to a condition called hyperosmia. Its causes vary; from pregnancy to differences in brain chemistry, scientists aren't quite sure why 'super-smellers' exist. Some studies suggest that a genetic mutation causes the overexpression of the KAL1 gene, which codes for a protein involved in the growth of nerve cells responsible for communicating smell information to the brain. There are several reasons why humans have evolved this ability, including food identification, avoiding dangerous substances and even recalling memories. However, smell can also act as a way to communicate with another person, particularly if that person is a potential partner. For decades, scientists have explored the role of odours in the attraction between two people. Some studies have suggested that our olfactory system can sniff out specific odours emitted by a person's immune system. When someone smells the scent of an immune system that is compatible with their own, they may find the owner of such a system more attractive than someone with an immune system that's too similar to their own.

DID YOU KNOW? Around five per cent of people are anosmic, with no sense of smell

PUTTING TASTE BUDS TO THE TEST

More than just a sense of gastronomic enjoyment, taste has played an important role in evolution. For example, sweetness acts as an indicator of sugar for energy, while the savoury taste of umami signals proteins and essential amino acids. Taste can also act as a warning sign for sour foods that are potentially spoiled and pose a health risk. To detect the basic flavours of salty, sweet, sour, bitter and umami, our tongues employ tiny structures called taste buds, which are packed into tiny protrusions on the tongue called papillae, to act as flavour detectives for incoming food. While the teeth and saliva break food down, the released chemicals bind with hair-like structures called microvilli, of which there are up to 150 per taste bud. The microvilli then generate a signal that travels through the nervous system to the brain for interpretation.



A microscopic view of papillae and purple-stained taste buds

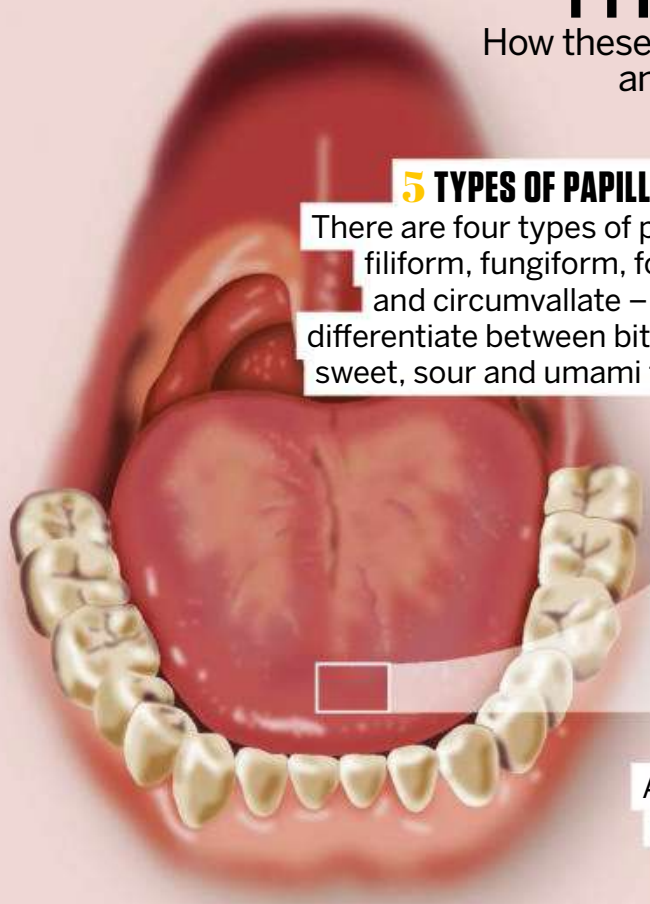
Tastes buds are regenerated every ten days, meaning damaged or scalded cells are quickly renewed

SUPER SENSE

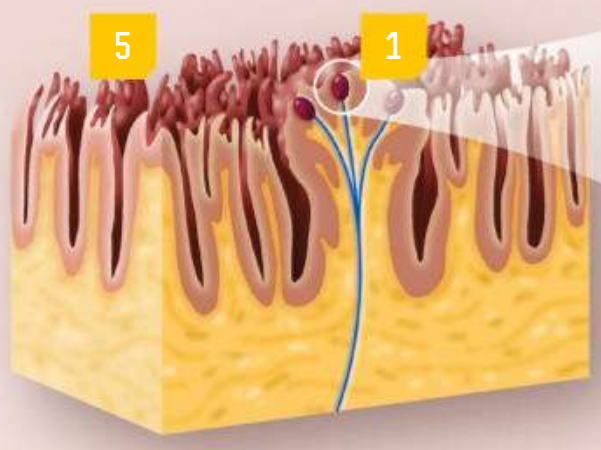
Around 30 per cent of the world's population have a supercharged sense of taste. They're known as supertasters, and like many other superpowers they owe their abilities to a genetic mutation, this one in a gene designated TAS2R38. There's an easy at-home experiment you can do to find out if you're a supertaster. All you need is a cotton swab, some blue food colouring, greaseproof paper and a hole punch. First, dip the cotton swab in the food colouring and wipe it on the tip of your tongue. The tongue's papillae don't soak up the food colouring and stand out from the dyed tongue. Then punch a hole out of a small piece of greaseproof paper and lay it on the tongue. This will allow you to count how many pink papillae there are on the tongue. If you're a supertaster then there will be more than 30 papillae within the circle, but if there's between 15 and 30 then you're a typical taster.

TASTE BUD STRUCTURE

How these microscopic structures gather information about flavour and why some people can taste better then others

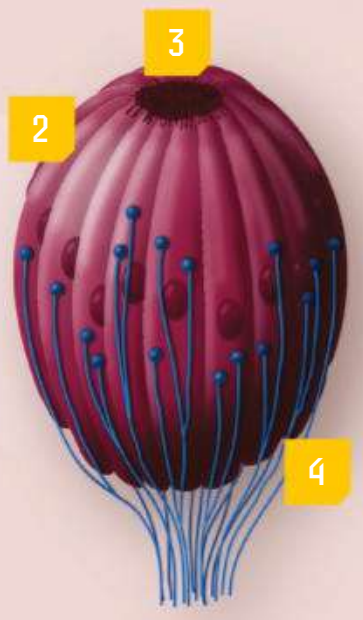


5 TYPES OF PAPILLAE
There are four types of papillae – filiform, fungiform, foliate and circumvallate – that differentiate between bitter, salty, sweet, sour and umami flavours.



1 PAPILLAE
Across the tongue, tiny intrusions called papillae form the sites for taste. Supertasters can have almost double the amount of papillae than average tasters.

2 BASAL CELLS
Surrounding stem cells that will eventually transform into taste receptor cells.



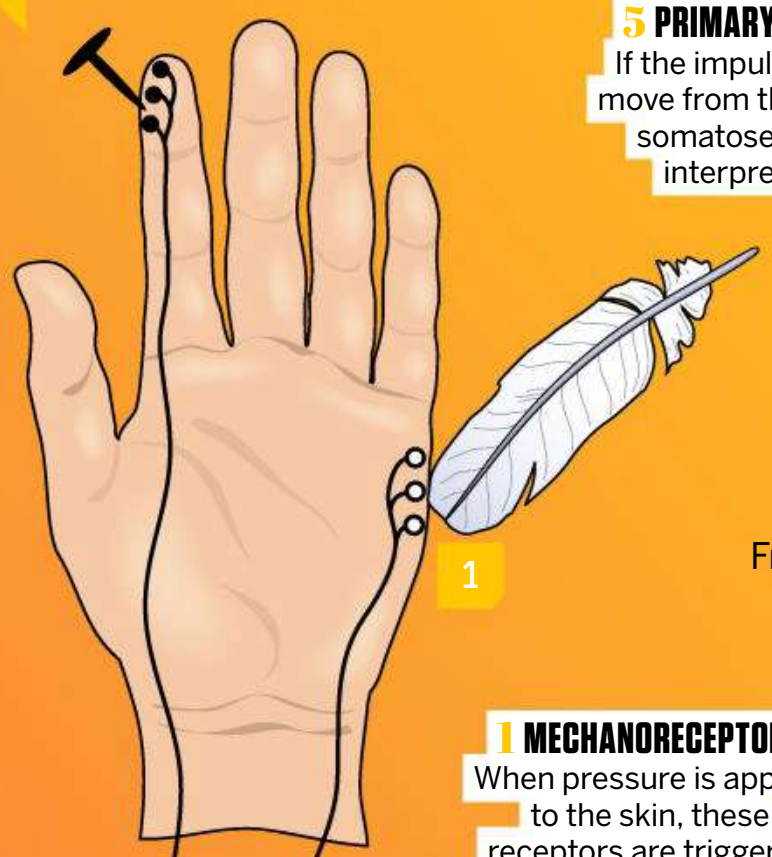
3 TASTE HAIRS
These hair-like cells come into contact with the chemical components of food and trigger an impulse to adjoining nerve cells.

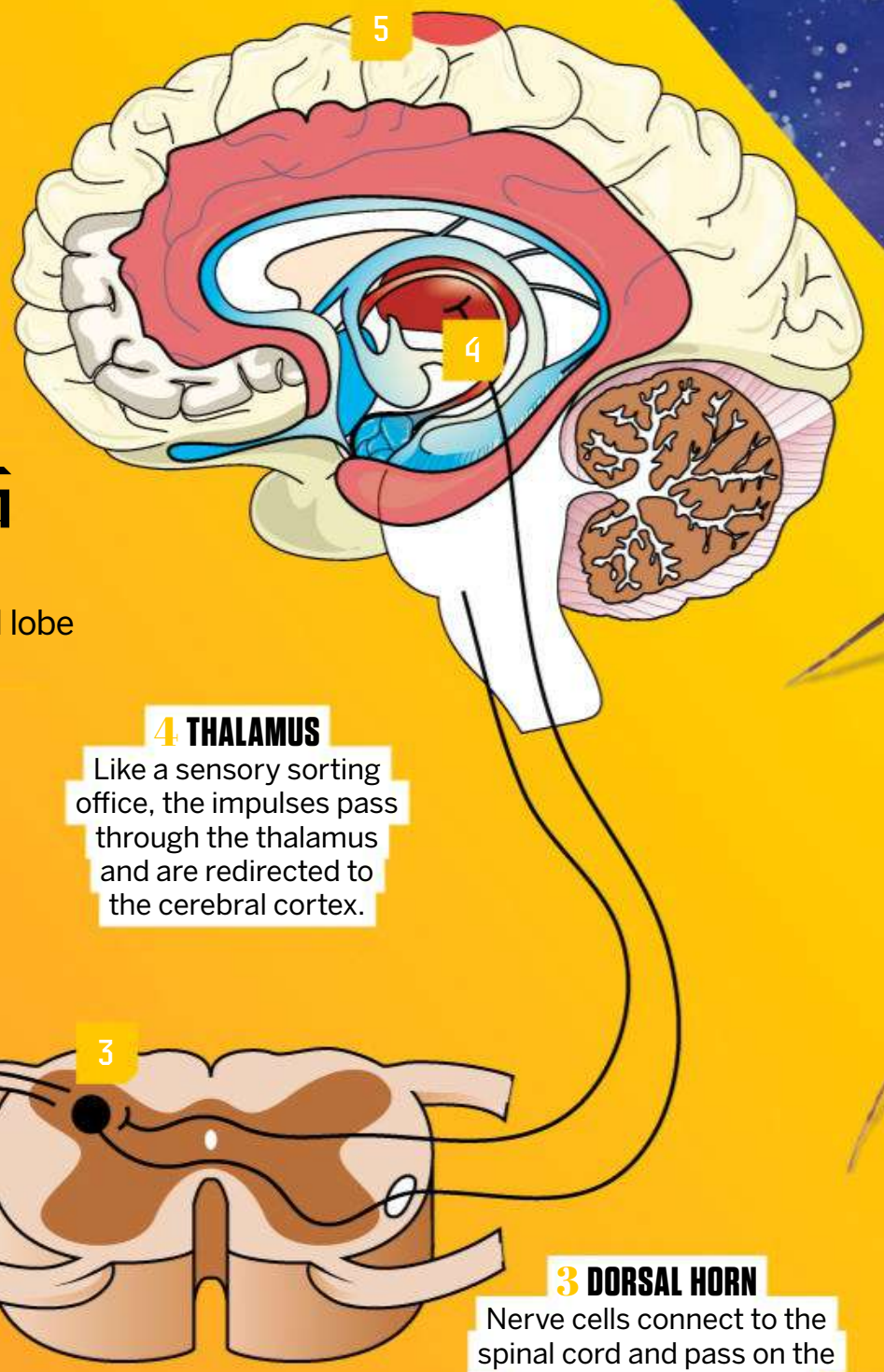
4 NERVE FIBRES
Different flavours trigger certain taste receptors and stimulate the corresponding nerve cells.

© Shutterstock / Science Photo Library / Getty

TOUCHING A NERVE

From fingertips to the frontal lobe on the journey of touch





1 MECHANORECEPTORS
When pressure is applied to the skin, these receptors are triggered and generate an electrical impulse.

2 NEURONS
The impulse is carried along the network of nerves that gather at the spinal cord.

3 DORSAL HORN
Nerve cells connect to the spinal cord and pass on the touch signal to sensory neurons within vertebrae.

4 THALAMUS
Like a sensory sorting office, the impulses pass through the thalamus and are redirected to the cerebral cortex.

5 PRIMARY SOMATOSENSORY CORTEX
If the impulse is strong enough, it will move from the thalamus to the primary somatosensory cortex, where it is interpreted and responded to.

FEELING TOUCH

The ability to feel our surroundings is one of the first senses humans developed. Unlike the other four classic senses, touch is multifaceted and is perceived as a result of multisense systems within the skin. However, when we talk about everyday touch we are referring to something called haptic touch. Embedded in the skin are an array of nerve cells called mechanosensory neurons, whose job is to let the brain know information about objects the skin comes into contact with. For example, nerve receptors called Pacinian corpuscles detect changes in pressure, whereas Ruffini corpuscles detect warmth. These nerve receptors then send electrical signals through the nervous system and along the spinal cord to the brain for interpretation. Under the umbrella of 'touch' is another type of sense called nociception. You might not have heard the term, but you'll be painfully aware of its existence. Nociception is the body's ability to recognise pain, and the nervous system communicates with the brain to react accordingly. For example, pricking your finger or stubbing your toe triggers pain receptors, found in the majority of bodily tissue, that raise the alarm bells in the brain via nerve cells travelling up the spinal cord. The brain then returns the signal through the nervous system to coordinate a response, such as contracting muscle to recoil limbs or releasing natural painkillers into the bloodstream.

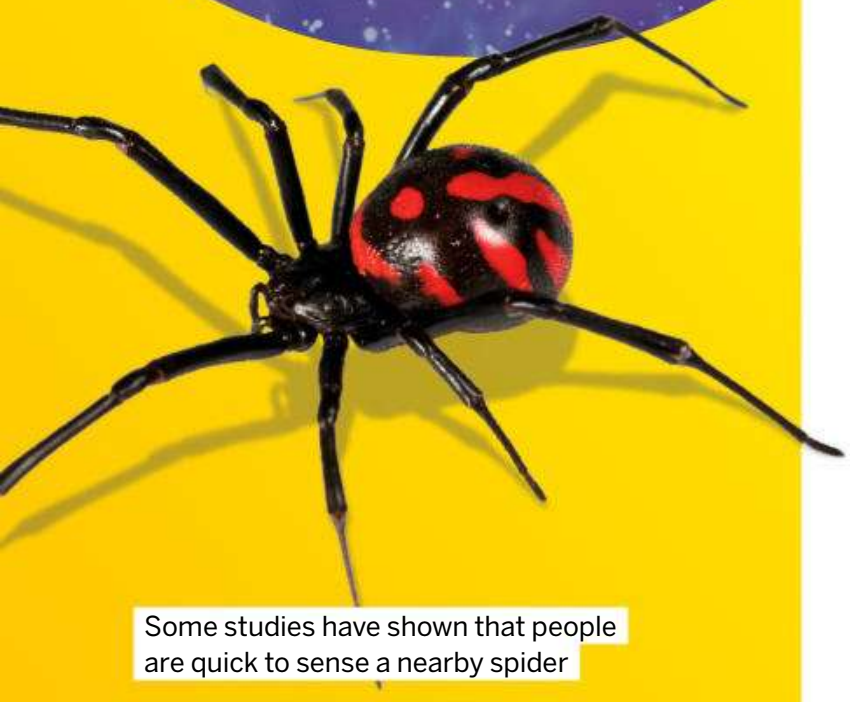
SUPER SENSE

In extremely rare cases, the function of pain receptors is thwarted, leading to what's known as congenital insensitivity to pain and anhydrosis. This dangerous disorder occurs when pain receptors and the nervous system aren't correctly connected to the brain, preventing the sufferer from feeling any pain, including injuries caused by extreme temperatures, cuts or bruises.

A fingertip has more than 3,000 touch receptors

Did you know?
The brain itself cannot feel pain

DID YOU KNOW? There are over 4 million touch receptors covering the entire human body



Some studies have shown that people are quick to sense a nearby spider

REAL-LIFE SPIDEY-SENSES

Unlike Spider-Man, whose Spidey-Sense saves him from imminent danger, humans may have a super sense that's reserved for detecting spiders. A 2014 study published in the journal *Evolution and Human Behaviour* found that study participants showed an unconscious sense for seeing spiders. Participants of the study were asked to complete a computer task with images of several objects, including a syringe, a housefly and a spider, shown on screen for 200 milliseconds, around the same time as a blink. The results showed that more than half of the participants noticed when the spider appeared on screen, compared to less than 15 per cent that noticed the image of the syringe and ten per cent of participants that recalled the housefly. It's not entirely clear to scientists why people might have a specific awareness of spiders, but some have suggested that it's an evolutionary leftover from a defence mechanism designed to protect us from dangerous animals.

UNCOVERING YOUR SIXTH SENSE

The term 'sixth sense' can conjure up thoughts of the supernatural. In some ways our bodies might actually be tuned to the workings of the paranormal or able to predict the future. While science is yet to prove the existence of a clairvoyant sixth sense, we do have a sixth and even seventh sense that we all experience every day, perhaps without realising. As well as using our senses to understand the world around us, the human body employs another sensory ability to understand what's happening within itself, called interoception. This is the body's way of making sure everything is working, patrolling through the body and taking stock of how internal systems and organs are functioning. For example, interoception alerts us when a hungry stomach needs filling or our full bladder needs emptying. Receptors within almost every piece of tissue in the body use the nervous system to communicate updates to the brain on their wellbeing, such as when making you aware that your heart is beating fast. Interoception also works to maintain harmony within the body, known as homeostasis.

Another lesser known sense is called proprioception. This addition to the senses is your brain's ability to monitor where your body parts are in the space around you – for example, when we close our eyes we are able to accurately place our fingers on our nose. The brain knows the relative position of both the nose and the finger and can successfully coordinate the movement of the hand to meet the nose. It's also the brain's way of knowing how far to extend limbs to grab an object or orientate legs for walking.

Proprioception allows our body to move through the world around us and gauge our physical position

EYES IN THE BACK OF YOUR HEAD

Have you ever had that feeling you're being watched or that someone in the crowd is looking at you? It's a phenomenon known as gaze detection, and it's the brain's way of keeping an eye on potential threats. Gaze has been an important part of human evolution. Unlike most other animals, humans have a large sclera, which is the white matter that surrounds the pupil. For most animals, a large sclera reveals their eyes, and therefore their presence, to potential predators. But humans use the sclera as a vital tool in communication to monitor eye movement and gaze. However, even when our eyes don't meet the gaze of another, our brain seems to know when someone is looking at us.

Studies have found that certain cells of the brain become active when somebody nearby is looking at you. Even shifting their gaze by only a few degrees from you is enough to stop the cells from activating. It's not fully understood how our brains do this, but some evidence suggests that when a person is in our peripheral vision, our brains substitute a person's head movement with a shift in their gaze, mistakenly alerting us that someone is looking our way.

Our brain can trick us into thinking there's someone staring at us

© Getty / Shutterstock

EXPLORING THE PACIFIC

WORDS SCOTT DUTFIELD

Hop aboard the ancient sailing vessels that carried new nations across the ocean

DID YOU KNOW? Māori voyagers first reached New Zealand around 1,000 years ago

Around 3,000 BCE, groups of people began their historic voyages from southeast Asia and Pacific islands such as New Guinea to discover the wealth of tropical islands dotted around the Pacific Ocean. Their first stop was the Solomon Islands, then the Vanuatu archipelago, before reaching the Fijian islands, Samoa and Tonga by around 1600 BCE. From there, voyagers sailed to eastern Polynesia and the Cook Islands by 300 BCE before venturing thousands of miles northwards to discover Hawaii around a hundred years later. The expansion of Polynesia ended around 1000 to 1250 CE when voyagers made their way to Aotearoa, now known as New Zealand.

We may never know the exact reason why the first Polynesians immigrated, although it's been suggested that competition for resources by other ancient civilisations, expulsion from their homelands or just good old-fashioned curiosity may have been the catalyst. What we do know is how they managed to cross thousands of miles of open water to discover what is now known collectively as Polynesia. To brave the unforgiving Pacific waters, early travellers boarded sailing canoes. Melanesian people of Fiji refer to them as drua, Tongans use the term kalia and the Samoans know them as 'alia, but what they all share in common is their design. These double-hulled sailing canoes were constructed from planks of native wood to form the boat's keel (underside) and its main body. Wood was bound together using coconut fibres and often glued together using the gum produced by plants such as the breadfruit tree. Some of these canoes spanned over 30 metres and carried as many as 100 people.

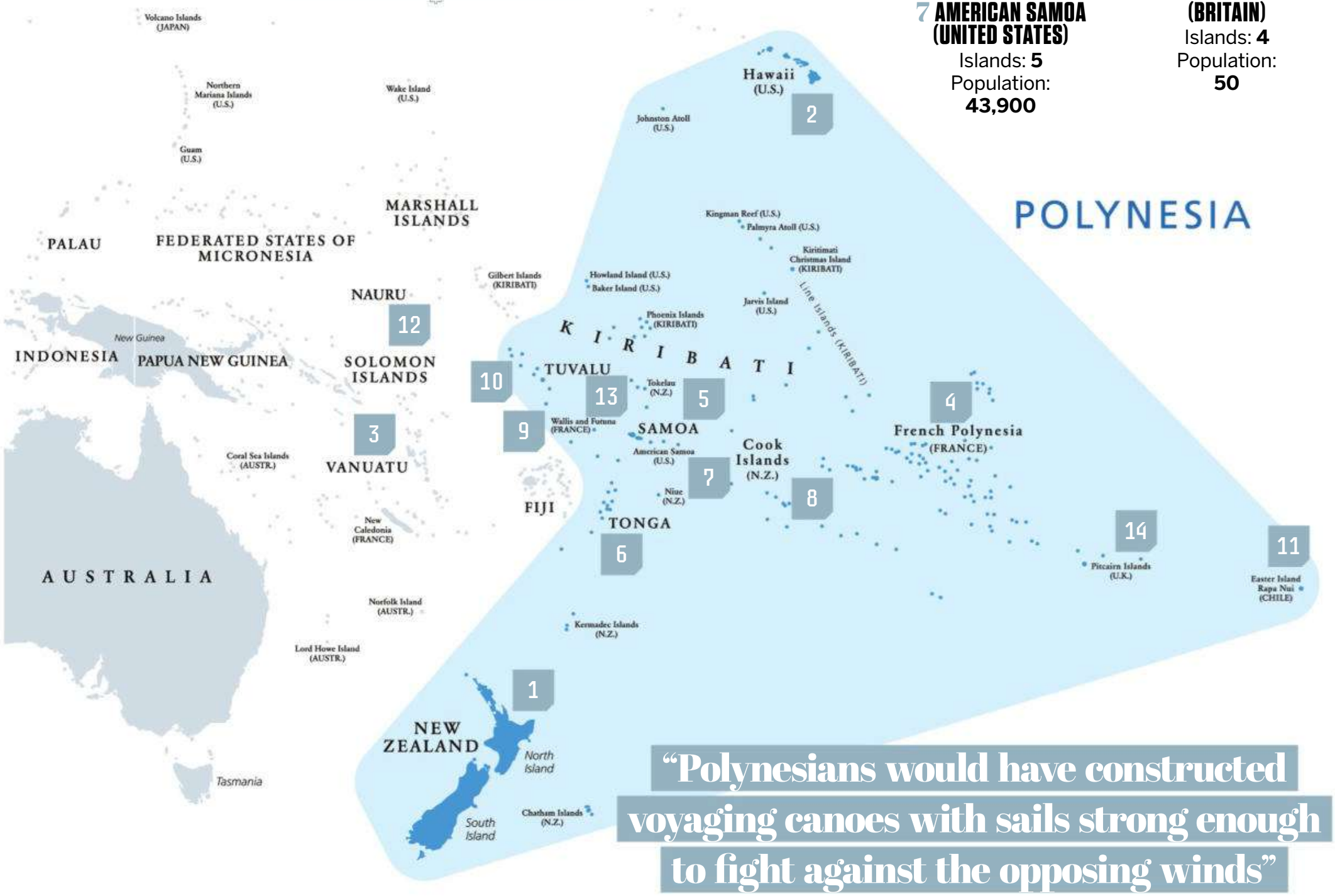
With only a hand paddle for steering and manual propulsion, the double-hulled canoes typically used a V-shaped sail, often referred to as the canoe's 'crab claw', to catch the power of

Did you know?

Wayfinders used songs to remember their voyage routes

THE POLYNESIAN TRIANGLE

There are more than 1,000 islands across Polynesia, making up around 118,000 miles of land



1 NEW ZEALAND
Islands: **600**
Population: **5,228,000**

2 HAWAII (UNITED STATES)
Islands: **137**
Population: **1,434,000**

3 VANUATU
Islands: **83**
Population: **334,500**

4 FRENCH POLYNESIA (FRANCE)
Islands: **118**
Population: **317,600**

5 SAMOA
Islands: **9**
Population: **224,000**

6 TONGA
Islands: **176**
Population: **107,700**

7 AMERICAN SAMOA (UNITED STATES)
Islands: **5**
Population: **43,900**

8 COOK ISLANDS
Islands: **15**
Population: **17,000**

9 WALLIS AND FUTUNA
Islands: **3**
Population: **11,500**

10 TUVALU
Islands: **9**
Population: **11,400**

11 EASTER ISLAND (CHILE)
Islands: **1**
Population: **8,600**

12 NIUE
Islands: **1**
Population: **1,900**

13 TOKELAU
Islands: **3**
Population: **1,900**

14 PITCAIRN ISLANDS (BRITAIN)
Islands: **4**
Population: **50**

"Polynesians would have constructed voyaging canoes with sails strong enough to fight against the opposing winds"

© Alamy / Shutterstock

the wind – that is if the wind was blowing in the right direction, something that scientists were left scratching their heads about for many years. Based on modern-day models, winds around the tropical Pacific Ocean blow east to west, known as easterlies. This meant that the ancient Polynesians would have constructed voyaging canoes with sails strong enough to fight against the opposing winds in order to move westward and discover the islands through central Polynesia, such as the Cook Islands. However, research carried out by climatologists in 2014 revealed that a switch in the direction of the wind may have occurred during the time of ancient voyages. For several decades, the wind's direction could have changed from east to west, giving seafarers a serendipitous window of opportunity to discover new islands. When the sails were raised and the ocean winds were high, it's estimated that these canoes could travel up to 155 miles in a single day. However, when the winds were low, seafarers relied on enormous steering paddles – some of which extended more than six metres – to propel the vessel through the water.

Did you know?

Hōkūleʻa has travelled over 140,000 nautical miles

A Samoan double-hulled canoe in Wellington Harbour, New Zealand

Without modern navigation technologies to guide them on their journey across the vast expanse that is the Pacific Ocean, ancient Polynesian seafarers had to rely on the world around them to lead them to their new homes. Known as route makers and wayfinders, their expert navigators used all manner of ingenious techniques to find new land. From the constellations above them in the sky to ocean swells, wayfinders uncovered remarkable patterns in nature that led them straight to new land. For example, they noticed that during the morning, seabirds fly towards open water to hunt for fresh fish, whereas at dusk the same birds journey back to land to nest. Also, observing cloud formations and the reflections of land on their undersides revealed potential new and unexplored places. The traditional methods of Polynesian canoe building and knowledge of navigation began to decline in the 17th century when Europeans began to colonise the Pacific. Around this time, voyage canoes were slowly replaced by European ships.

BRINGING CANOES BACK TO HAWAII

In 1975, the Polynesian Voyaging Society launched a new generation of voyaging canoes, including Hōkūle'a. It was the first time in almost 600 years that a traditional canoe of this kind was constructed in Hawaii. This type of Polynesian canoe is reminiscent of the same vessels that saw the first settlers journey through the ocean from the Marquesas Islands around 1,000 to 2,000 BCE. The 19-metre-long double canoe sailed all around Polynesia, including its famous long-distance voyage from Hawaii to Tahiti in 1976, which was a 2,627-mile journey.

The Hōkūleʻa canoe anchored off Aloha Tower, Oahu, Hawaii

A va'a outrigger in South Tarawa, Kiribati

PERSONAL VESSELS

As settlements emerged throughout Oceania and Polynesia's many islands, canoes weren't just used for grand maritime explorations, but also to carry out day-to-day tasks. Smaller canoes known as va'a outriggers were paddle-operated for personal or small group use, designed for short fishing and transport journeys around islands. These narrow boats utilised a counterweight pendulum for stability and balance in the water. Like their larger sailed cousins, they were made from local wood, as well as coconut husks, shells and even bone. Along with the hands of skilled craftsmen, the construction of these vital vessels was overseen by a priest who blessed them with the protection of the gods while out at sea. Va'a are still used today around Polynesia as a traditional way to travel, although they have also found themselves at the heart of sporting events, including 1,500-metre-long lagoon sprints and 100-mile offshore marathons.

DID YOU KNOW? Easter Island was named by European explorer Jacob Roggeveen

An example of double-hulled drua at the New Zealand Maritime Museum

ABOARD THE OUTRIGGER

How these early vessels were built to brave the open waters of the Pacific Ocean

8 MAST
Sails were raised and lowered along bamboo masts, which were much shorter than modern-day yachts'.

4 STEER OAR
Wooden oars were used as the canoe's rudder and to improve the stability of these large vessels.

2 LASHINGS
The planks of wood that formed the hulls and deck of the boat were fastened together using the fibres of coconuts and other plants, which were twisted and braided to form rope.

6 DECK
Canoe builders used local hardwoods, such as the trunks of banana trees, to build the bulk of the canoes.

7 HULL
For longer voyages, a double hull was constructed to increase stability on the waves and allow them to carry more passengers.

1 SAIL
Sails were typically woven from tough pandanus leaves.

5 WIND INDICATORS
Some outriggers, particularly those made in Hawaii, used feathers known as lei hulu to indicate wind direction.

3 CABIN
Supplies such as food were stored in a small wooden cabin at the centre of the deck.

© Shutterstock / Alamy / Getty

WHY WE'RE MADE OF STARDUST

DID YOU KNOW? In 1929, a newspaper quoted astronomer Harlow Shapley as saying: "We are made of the same stuff as the stars"

JUST

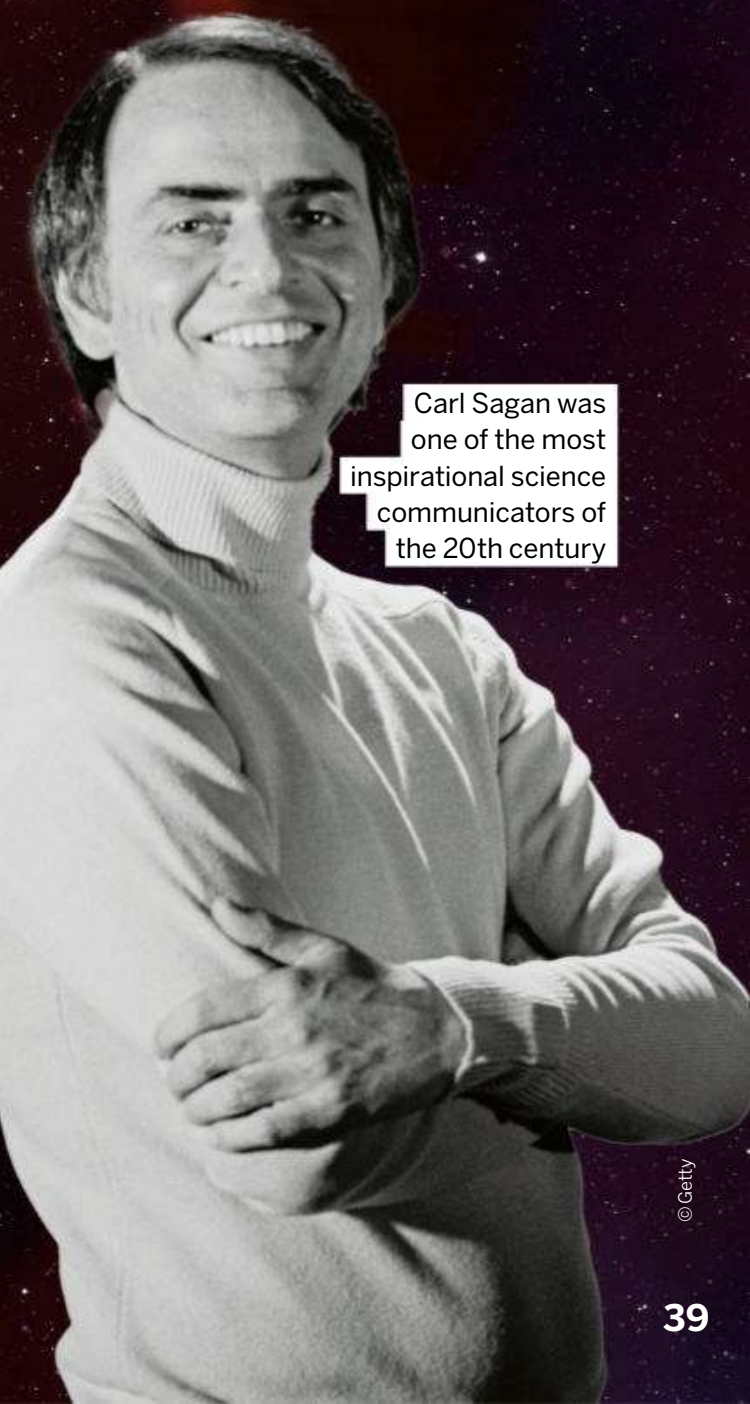
Human beings – and everything else – are made from recycled elements that came from stars

WORDS ANDREW MAY

You may have heard people say that human beings are 'made from stardust', perhaps with vaguely mystical overtones suggesting that this makes us unique or special in some way. But there's another perfectly scientific sense in which we really are made up of material from the stars – but this doesn't mean we're special or unique at all.

One person who understood the science behind the phrase was the astronomer Carl Sagan, who brought the idea to a whole new audience in the 1980s when he proclaimed on his TV show *Cosmos*: "We're made of star stuff!" The context in which Sagan used the phrase on that occasion was actually quite poetic – which is why so many people remember it – but a decade earlier, in his book *The Cosmic Connection*, he explained the hard scientific reality behind it: "The iron in our blood, the calcium in our teeth and the carbon in our genes were produced billions of years ago in the interior of a red giant star."

On first hearing, this might indeed suggest that there's something otherworldly about human beings – that we have a profound inner connection to the cosmos. In a sense this is true, but there's a catch. The same can be said of everything else on Earth too – trees, insects, rocks, bacteria and anything else you care to think of. They're all made up of star stuff just as much as we are. All material objects are composed of various combinations of the same limited number of chemical elements, and these elements are constantly being recycled all over the planet. If you go back far enough in time, Earth itself was made from recycled elements, and ultimately, the place they were recycled from was the stars.

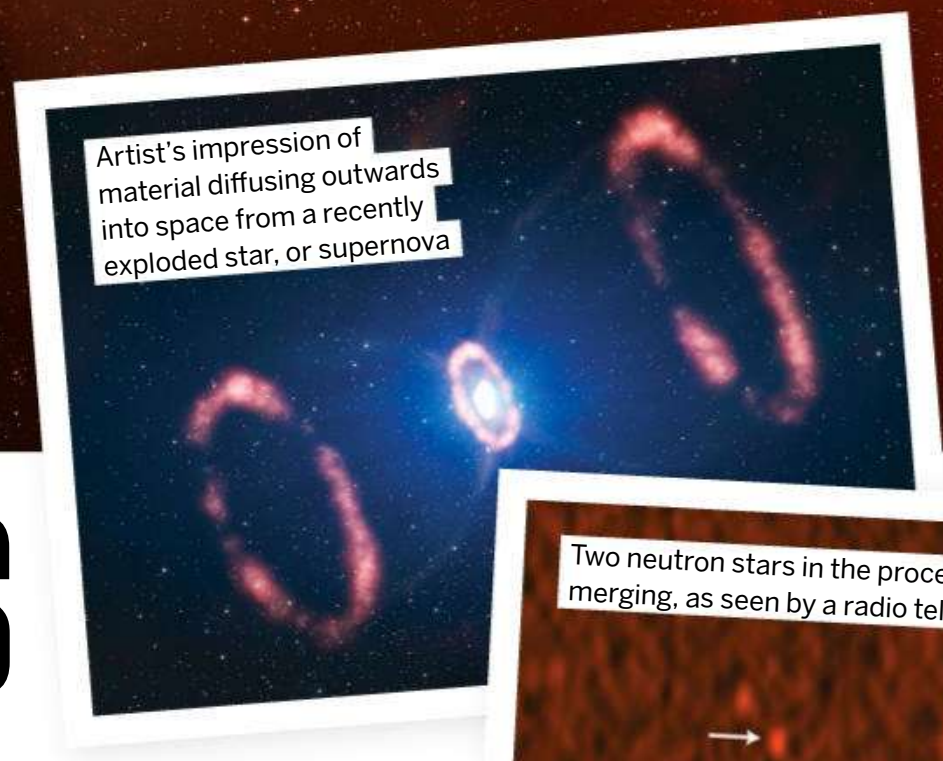


Carl Sagan was one of the most inspirational science communicators of the 20th century

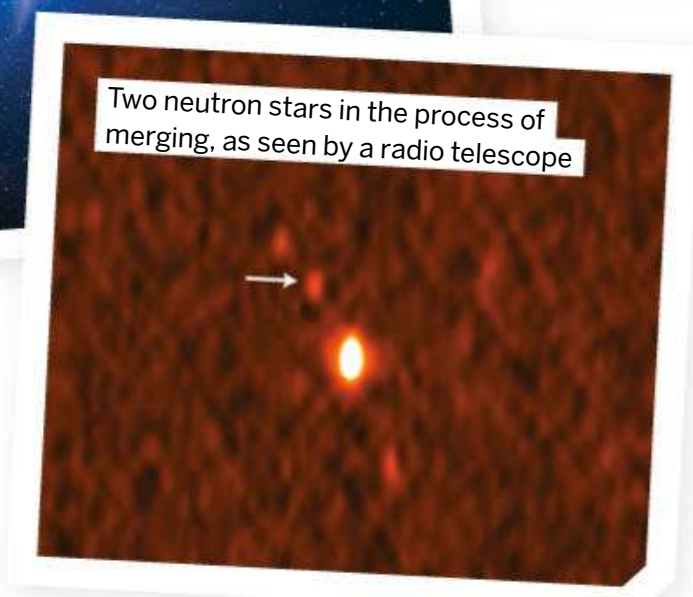
© Getty

In the far future when our Sun is dying, it will disgorge material into space

ORIGIN OF THE ELEMENTS



Artist's impression of material diffusing outwards into space from a recently exploded star, or supernova



Two neutron stars in the process of merging, as seen by a radio telescope

A huge variety of chemical compounds make up the world around us, from the minerals in rocks to the DNA in our cells. But all of these compounds are made up of different combinations of the same basic elements, of which a mere 92 are found in Earth's crust and biosphere. This rarely occurs in nature, which means Earth is essentially stuck with the same proportions of different elements that it started out with. But where did the elements come from in the first place? They're the result of a process called nucleosynthesis, which produced the atomic nuclei that are an element's basic building blocks. Some nucleosynthesis occurred in the very first moments of the universe, immediately after the Big Bang, when isolated protons formed the nuclei of hydrogen atoms. This is the lightest of all elements, followed by helium with two protons and lithium with three. And to make things a little more complicated, these heavier nuclei contain neutrons as well as protons, but this only affects their weight and not their chemical properties.

Although the primordial phase of nucleosynthesis following the Big Bang filled the universe with matter, this was all in the form of very lightweight elements – around three-quarters hydrogen, one-quarter helium and trace amounts of other elements. There was no hint at that stage of some of the most important elements from our own point of view, such as carbon, which has six protons, and in its most common form six neutrons.

This is where stars come to the rescue. They produce their heat and light through a process called nuclear fusion, which means exactly what it says – joining the nuclei of lighter elements together to make heavier ones. Stars can fuse hydrogen to make helium, which we already had from the Big Bang, but then carry on to heavier elements, including ones like carbon and oxygen that are so important to us. In the course of time, these new elements found their way into the interstellar medium – the extremely tenuous gas and dust pervading the space between stars. This is constantly replenished by the stellar winds that blow outwards from stars all the time, and from their final disintegrations – or dramatic explosions in the case of very massive stars – when they run out of material for nuclear fusion and die.

However, the death of one star isn't the end of the story; it's just a step in an ongoing process of cosmic recycling. Some of that chemically rich material in the interstellar medium will eventually become dense enough to collapse down into a nebula, and from this a whole new generation of stars can be born. That's what happened in this part of the galaxy around 4.6 billion years ago, when a star-forming nebula created what, in cosmic terms, was a group of 'third-generation' stars, made from material that had already been cycled through two stellar generations since the Big Bang. One of these new stars was our Sun, and after its formation it would have been encircled by a dusty disc containing atoms of all the 92 naturally occurring elements. It was from this disc that all the planets of the Solar System eventually formed – including our own. While we may think of our bodies and all the everyday objects around us as being 'down to Earth', they're ultimately made from atoms that originated in the depths of space.

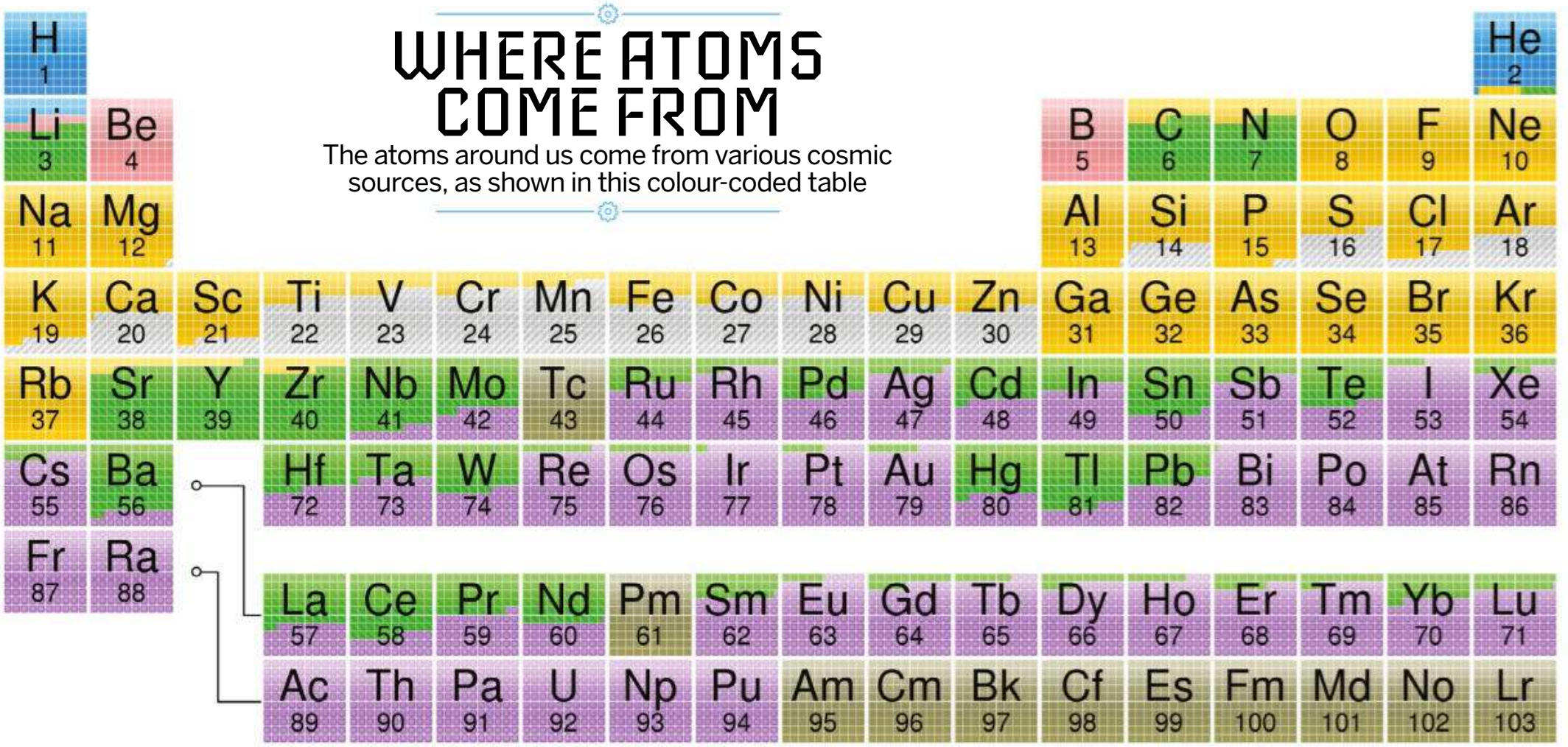
Did you know?

The first human-made element was technetium, created in 1937

DID YOU KNOW? The conventional portrayal of the sequence of elements, called the periodic table, dates from 1869

WHERE ATOMS COME FROM

The atoms around us come from various cosmic sources, as shown in this colour-coded table



BIG BANG

The first matter in the universe was formed in the first three minutes after the Big Bang. This mostly took the form of hydrogen (H) and helium (He), and it still accounts for all the hydrogen atoms in the universe, including those in Earth's water (H^2O).

DYING LOW-MASS STARS

Most atoms heavier than helium were created by nuclear processes inside stars. In the case of dying low-mass stars, the elements recycled into space include carbon (C) and nitrogen (N).

MASSIVE SUPERNOVAE

Perhaps the best known example of cosmic recycling occurs when a massive star explodes. Supernovae are the source of many of common elements around us, including oxygen (O), sodium (Na), aluminium (Al) and silicon (Si).

HUMAN SYNTHESIS

Some of the heaviest elements don't exist in a form that's stable over long periods of time. These elements don't exist in nature, but can briefly be created in high-energy particle accelerators.

COSMIC RAY FISSION

Fission breaks large nuclei into smaller pieces. Fission can be triggered by cosmic rays passing through the interstellar medium, and it's the main source of the elements beryllium (Be) and boron (B).

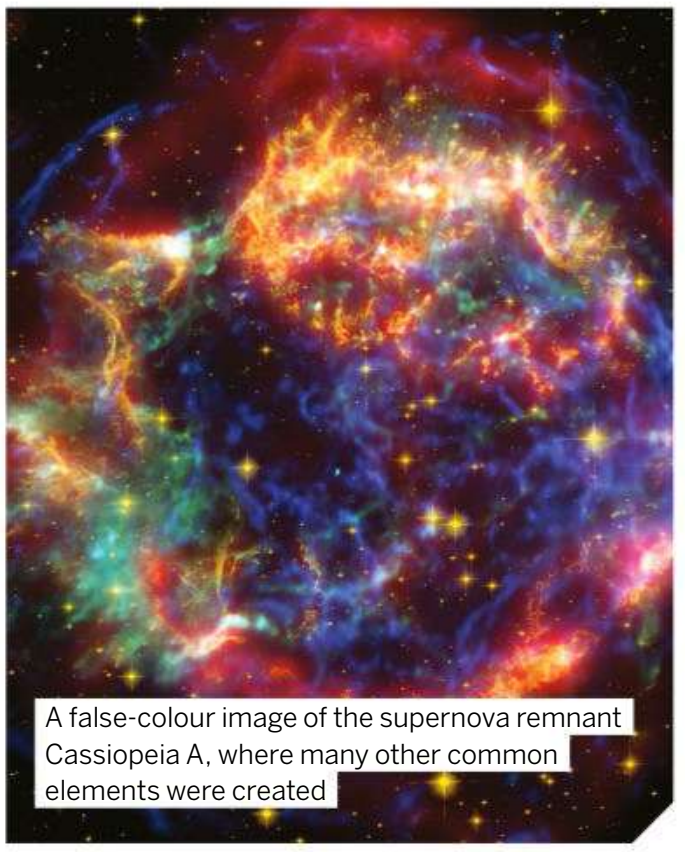
MERGING NEUTRON STARS

Neutron stars are ultra-compact stellar remnants. When two collide, they can produce much heavier nuclei than those commonly found inside ordinary stars, including elements such as gold (Au), platinum (Pt) and uranium (U).

EXPLODING WHITE DWARFS

Sometimes, a dead white dwarf star can accrete enough additional matter from a companion star to undergo a mini-supernova itself, producing elements such as chromium (Cr), iron (Fe) and nickel (Ni).

Helium and hydrogen were produced in the Big Bang, and respectively account for 25 and 73 per cent of the atoms in the visible universe



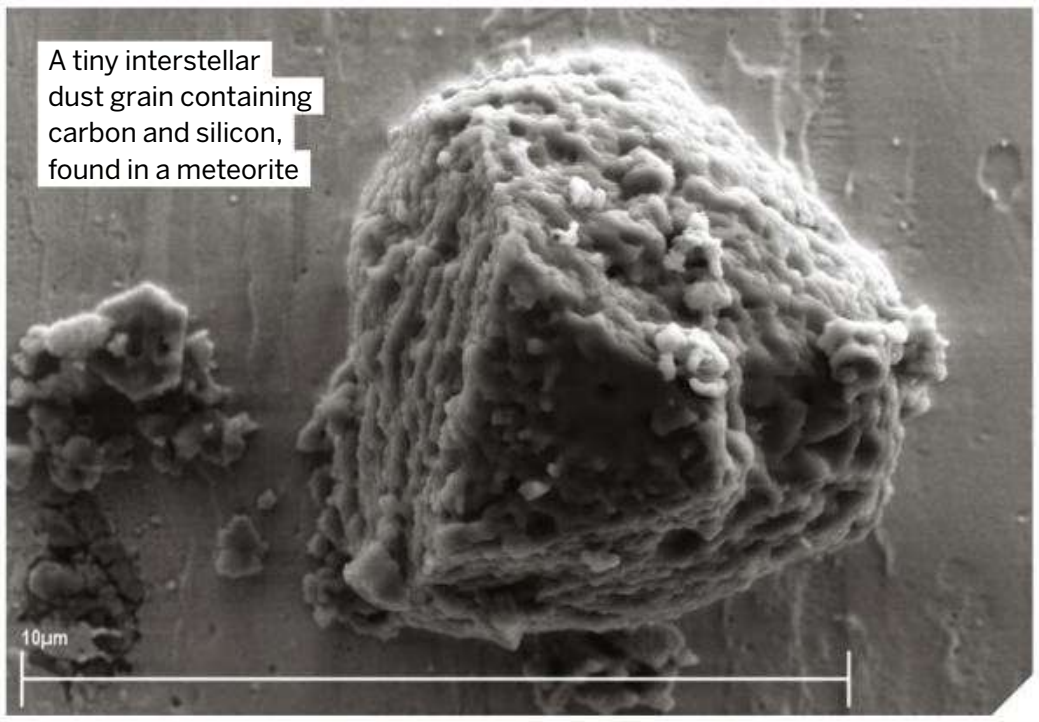
A false-colour image of the supernova remnant Cassiopeia A, where many other common elements were created

Heavy metals such as gold are only forged in rare and extremely high-energy phenomena such as neutron star mergers

© Periodic table: Cmglee / ESO / Alamy

WHAT IS STARDUST?

While ‘stardust’ is a poetic rather than technical term, the heavier atoms thrown out by stars into the interstellar medium really do clump together in the form of tiny dust grains. As these grains drift around the universe, they can sometimes be accreted onto asteroids in our own Solar System, and if a fragment of one of these makes it to the surface of Earth in the form of a meteorite, we can actually get our hands on a grain or two of ‘stardust’. In 2018, for example, a team at the University of North Carolina identified several grains of stellar dust that predate the formation of the Solar System.



A tiny interstellar dust grain containing carbon and silicon, found in a meteorite

OUR COSMIC ORIGINS

The chemical elements making up our bodies all came from outer space

OXYGEN 65%
The oxygen atoms making up almost two-thirds of our body mass originated in supernova explosions.

CARBON 18.5%
Around a quarter of our carbon originated in supernovae, but the rest of it came from dying low-mass stars.

HYDROGEN 9.5%
All of our hydrogen atoms – which are lightweight, hence the lower percentage of body mass – originated in the Big Bang.

NITROGEN 3.2%
Three-quarters of our nitrogen comes from low-mass stars, and the rest comes from supernovae.

CALCIUM 1.5%
Just over half of our calcium originated in supernovae; the rest comes from exploding white dwarf stars.

PHOSPHORUS 1%
Phosphorus comes from supernovae and exploding white dwarfs, but in different proportions – around 97:3.

POTASSIUM 0.4%
For potassium, the ratio is around 82 per cent supernovae to 18 per cent exploding white dwarfs.

SULPHUR 0.3%
Our sulphur atoms come roughly 58 per cent from supernovae and 42 per cent from white dwarf explosions.

SODIUM 0.2%
Sodium is another element that, like oxygen, derives entirely from supernovae.

CHLORINE 0.2%
Chlorine is another mix of supernovae and exploding white dwarfs, this time in the ratio of 84:16.

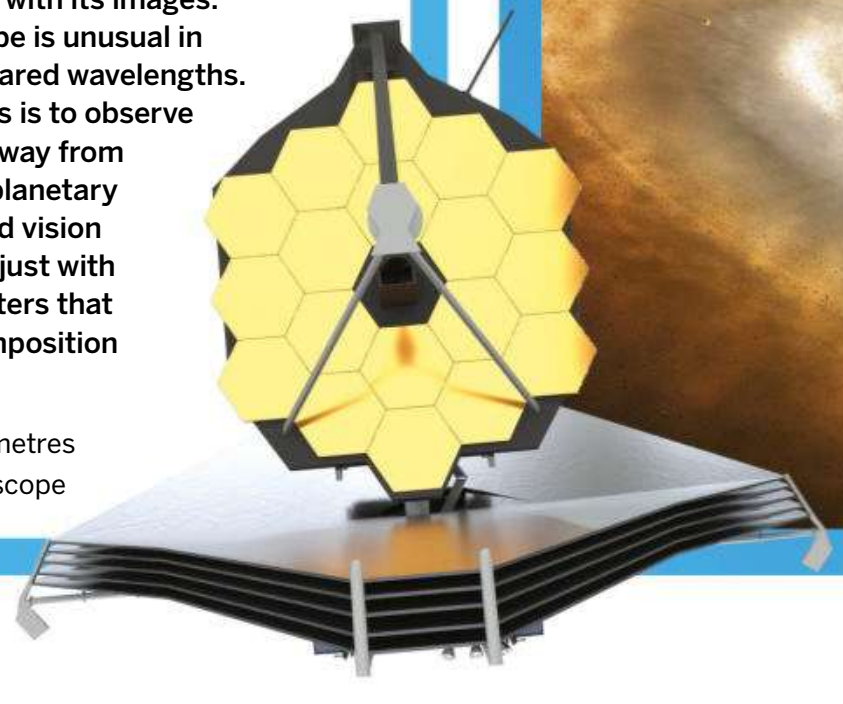
MAGNESIUM 0.1%
Like oxygen and sodium, magnesium is another element that comes solely from supernovae.

Did you know?

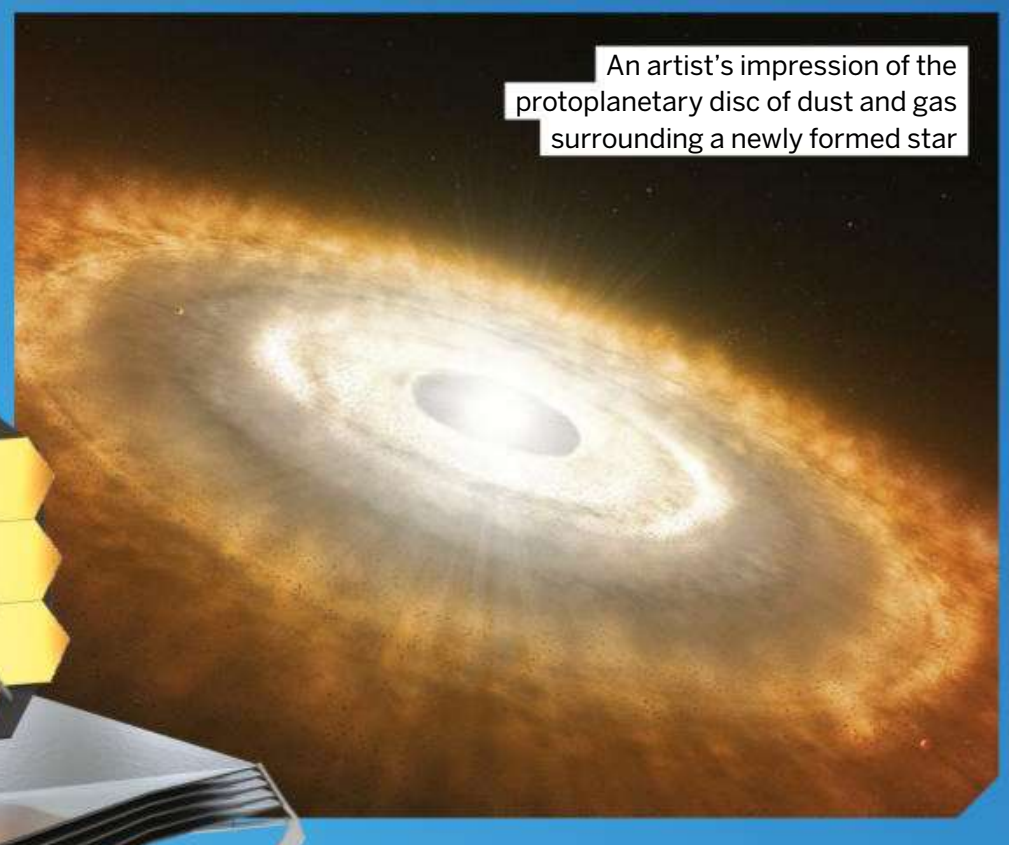
Helium is so rare on Earth that it was first seen in space

OBSERVING THE BIRTH OF STARS

It’s easy to say that the Sun and its planets formed from elements created in a previous generation of stars, but how do we know that? We can see the same processes going on today, where the latest generation of stars are just being born. One of the most important tools allowing astronomers to study these processes is NASA’s James Webb Space Telescope, which has already stunned the world with its images. Aside from its huge size, the telescope is unusual in observing the universe mainly at infrared wavelengths. One of Webb’s principal science goals is to observe the process of star formation all the way from its initial stages to the formation of planetary systems like our own. Webb’s infrared vision can pierce through cosmic dust, not just with imaging sensors but also spectrometers that allow it to work out the chemical composition of what it’s seeing.



Webb’s gold-plated mirror is 25 square metres in area, larger than any other space telescope



An artist’s impression of the protoplanetary disc of dust and gas surrounding a newly formed star

DID YOU KNOW? In October 2023, Webb detected the heavy element tellurium in the aftermath of a neutron star merger

WEBB VERSUS HUBBLE

THE PILLARS OF CREATION

This iconic view was first photographed by NASA's Hubble Space Telescope in 1995, and then a second time in 2014 to produce the image below. Located in a star-forming region called the Eagle Nebula, the pillars are made of interstellar dust – or 'stardust' if you like. They make a truly impressive sight, but have the disadvantage for astronomers of concealing many of the newly formed stars. In contrast, the pillars have become semi-transparent in Webb's infrared view, revealing in far more detail what is going on in this stellar nursery.

CARINA NEBULA

Here is another comparison between Hubble and Webb's views of a star-forming region – in this case a young star cluster called NGC 3324 inside the Carina Nebula. The story here is essentially the same as with the Pillars of Creation. What looks like a dense, almost rocky landscape in Hubble's image becomes a semi-transparent veil when seen in the infrared by Webb. This provides astronomers with a crystal-clear view of newly formed stars – and the protoplanetary discs encircling them – that no telescope has ever seen before.

3 The average number of supernovae per galaxy per century

67 A lot of chemical elements have been observed to exist in the Sun

10 BILLION YEARS A Sun-like star has a life span twice the age of Earth

ISOTOPES ARE VERSIONS OF ELEMENTS WITH DIFFERENT NUMBERS OF NEUTRONS

SALT IS MADE OF TWO COMMON ELEMENTS: SODIUM AND CHLORINE

24 Two dozen elements have been made by humans in particle accelerators

2:1 Ratio of atomic mass of gold to that of hydrogen

73% Nearly three-quarters of the visible universe is composed of hydrogen

© Getty / ESA / NASA / University of North Carolina

1 SAFE VIEWING

Unlike solar eclipses, it's perfectly safe to look directly at a lunar eclipse with the naked eye, as you're actually looking away from the Sun. Indeed, an eclipsed Moon is actually dimmer than a full Moon.

1

WHAT HAPPENS DURING A LUNAR ECLIPSE?

WORDS MARK THOMPSON

In 2024 we'll have two different eclipses of the Moon. But how do they happen, and why do total lunar eclipses turn our natural satellite red?

Civilisations have been captivated by lunar eclipses for centuries, long before humankind understood how they occur. The Mayans perceived that the Moon was being swallowed by a jaguar, while Chinese astronomers contested that a three-legged toad was responsible for devouring our orbiting neighbour. But as the years passed and our scientific knowledge grew, observation and measurement began to replace folklore and the true nature of lunar eclipses was uncovered.

Lunar eclipses occur when the Sun, Earth and Moon align in such a way that the Moon passes through the shadow, or umbra, of our planet, briefly blocking sunlight from illuminating its surface. It will happen twice in 2024: on 25 March and 18 September. If you look at the sky at any time of year, you will see the Sun, Moon and stars rise in the east and set in the west. This apparent motion is the result of Earth rotating on its axis as it orbits around the Sun. At the same time, the Moon is in orbit around Earth. The changing relative positions of the three bodies is the cause of the changing lunar phases – much of the Moon's surface is illuminated from our vantage point at any one time – as well as the rarer and more mysterious lunar eclipses.

DID YOU KNOW? There are three types of lunar eclipse: total, partial and penumbral

2 RED MOON

If Earth had no atmosphere, the Moon would disappear during a lunar eclipse. Instead it appears reddish because the green-to-violet portion of the light spectrum is filtered out by our atmosphere. This effect also reddens the sky at sunset.

2

Did you know?

The Danjon scale measures eclipse brightness on a five-point scale

It would be reasonable to expect lunar eclipses to be a more common occurrence than they actually are. They take place when Earth falls directly between the Sun and the Moon, so why isn't every full Moon accompanied by an eclipse? The answer is that the orbit of the Moon is tilted by five degrees to Earth's orbit around the Sun, so sometimes the Moon is slightly above or below the Earth-Sun line at full Moon. It is only when the three objects are perfectly aligned that a lunar eclipse can be observed.

During an eclipse, the Moon almost disappears as it drifts into our planet's shadow. But while it is in the shadow, the Moon doesn't vanish from our skies as you might expect. Instead it shines either a dark, murky brown or bright, vivid red colour as it's illuminated by sunlight that was scattered as it passed through Earth's atmosphere. The colouration of the surface depends on various factors, such as the temperature, humidity and amount of dust in our atmosphere. To witness this spectacle for yourself is to understand why ancient civilisations were so fearful of these strange yet beautiful phenomena.

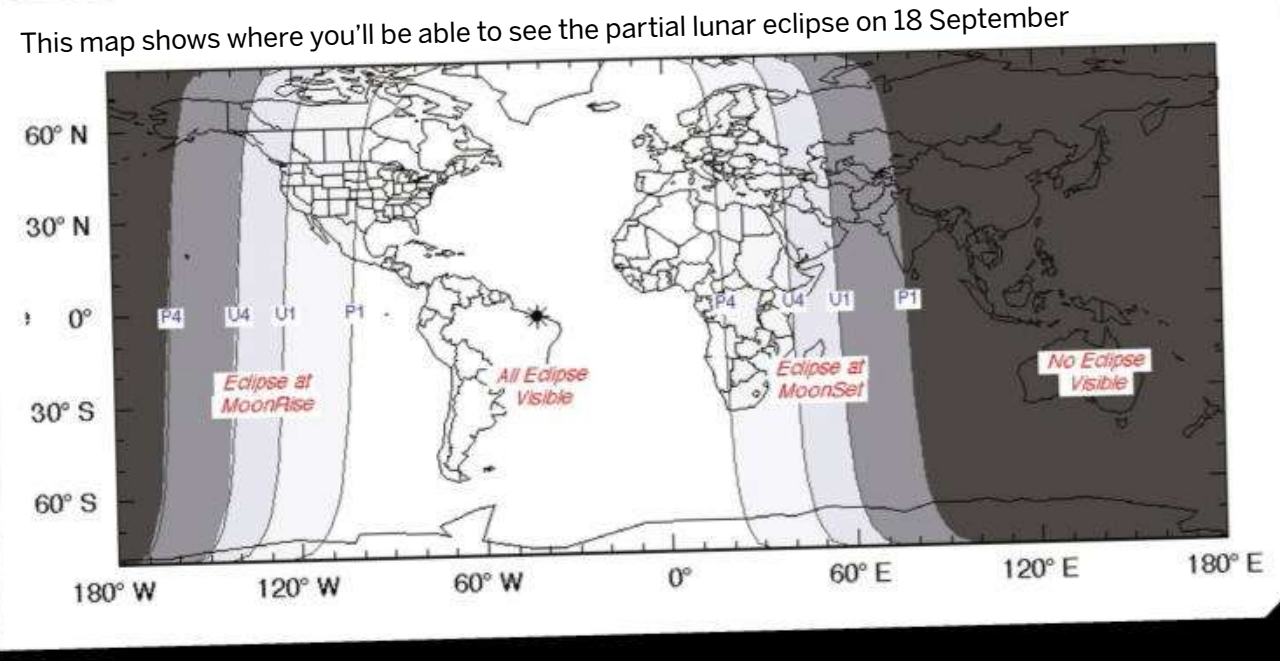
WHEN TO VIEW THE PARTIAL ECLIPSE

The partial lunar eclipse on 18 September 2024 will start at 01:41 in the UK, peak at 03:44 and end at 05:47. The only parts of the world that will be able to view the eclipse in its entirety will be South America, some eastern US states, most of Europe and the western half of Africa.

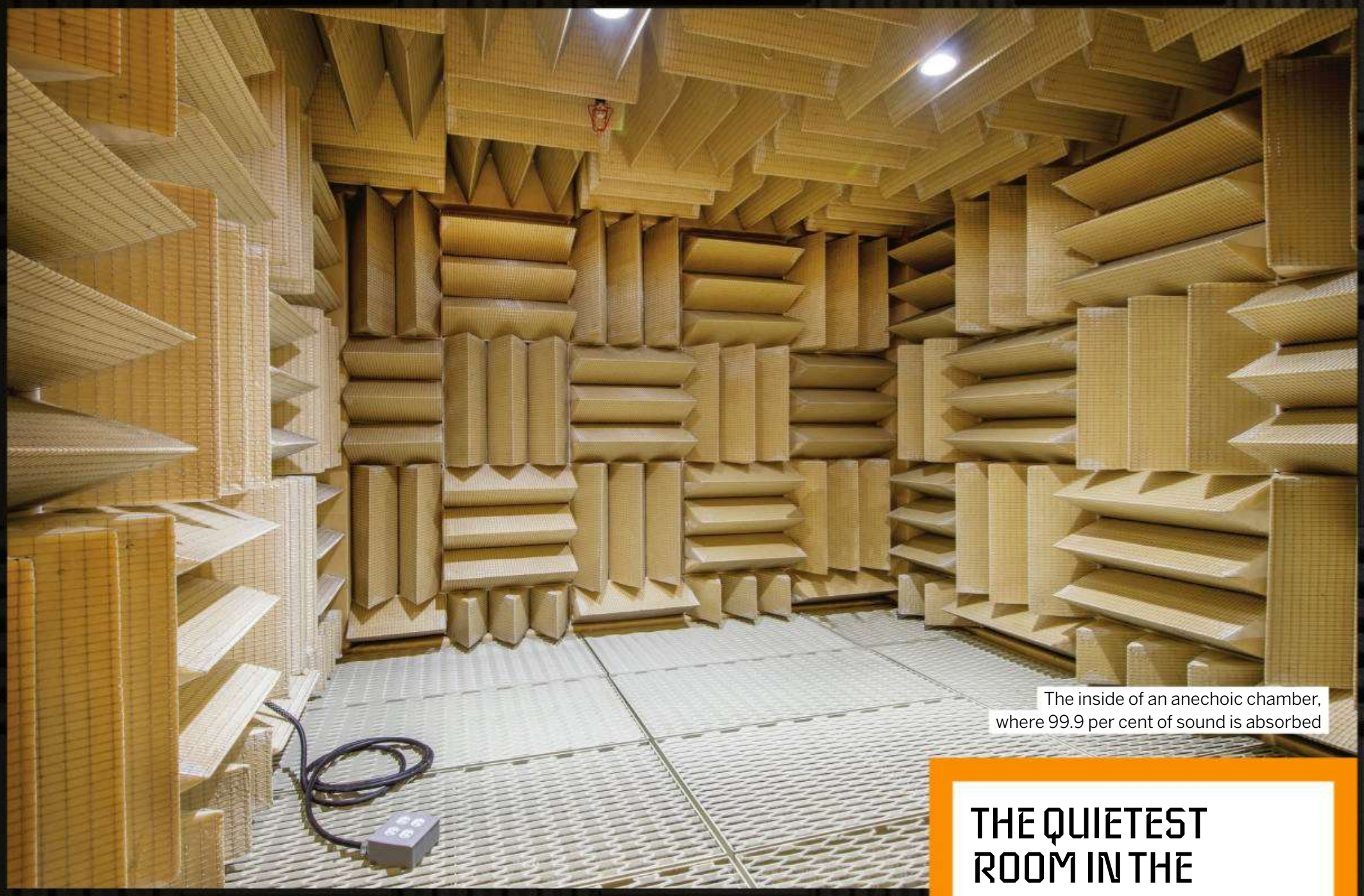
The map below illustrates which parts of the world will be able to view the lunar eclipse, and to what degree. In the eastern US the eclipse will be visible from 20:39 (EDT) on 17 September and end at 00:49 (EDT) on 18 September.

The other lunar eclipse in 2024, a penumbral lunar eclipse on 25 March, will be entirely visible in most of North America and South America. In 2025 there will be no less than three total lunar eclipses to look forward to. There will also be a total solar eclipse on 8 April 2024. Here, the Moon passes in front of the Sun and entirely obscures it.

This map shows where you'll be able to see the partial lunar eclipse on 18 September



© NASA, Wang, Letian



The inside of an anechoic chamber, where 99.9 per cent of sound is absorbed

SOUNDPROOFING IN ACTION

Noise can be a real nuisance in the wrong place, but the volume can be turned down using the right shapes and materials

WORDS SCOTT DUTFIELD

Whether it's the invading vibrations of outside traffic or the cacophony of sounds created by TVs and smartphones, our homes are a hotbed of sound waves. The basic science of sound is simple: when an object vibrates, it causes the molecules in the air to collide with one another in a domino effect that creates a wave of sound. The wave is only heard when our eardrums are hit by the sound wave and our brain interprets the sound. Our eardrums can only hear sound waves if the vibrations are a certain frequency. Anything lower than 20 vibrations per second and the human ear can't hear it, and similarly, anything over 20,000 vibrations per second is too high for the ear to detect. The size of sound waves, known as amplitude, determines how loud the sound is heard, which typically relates to the force used to create the vibrations. For example, the harder you hit a nail into a piece of wood, the more the nail will vibrate when

THE QUIETEST ROOM IN THE WORLD

Welcome to the anechoic chamber, the world record holder for the quietest place on Earth. Located in Orfield Laboratories in Minnesota, this sensory-confusing room is so quiet that the sound levels inside it measure -24.9 decibels. By comparison, a typical quiet room is around 30 decibels. The chamber consists of concrete walls lined with 10.5-centimetre-thick steel plates. Fibreglass wedges also extend 85 centimetres into the room from each of the room's six sides, including the floor. A mesh suspension flooring is used for people to stand inside, but it's reported that people can't withstand being inside for more than 45 minutes. With the complete absence of background noise, the human body itself becomes the only source of sound. Over time, the ears adapt to the external silence and pick up on movements within the body, including hearing your lungs inflate, blood circulating in the brain and stomach digestion, which can be too much for some people to bear.

DID YOU KNOW? The speed of sound is around 761 miles per hour at sea level

struck, and the louder the sound. But sound waves aren't just airborne vibrations. Known as impact noise, these sound waves are generated when one object, such as a floor or door, is impacted by another object, such as your foot or hand, causing it to vibrate and emit sound waves.

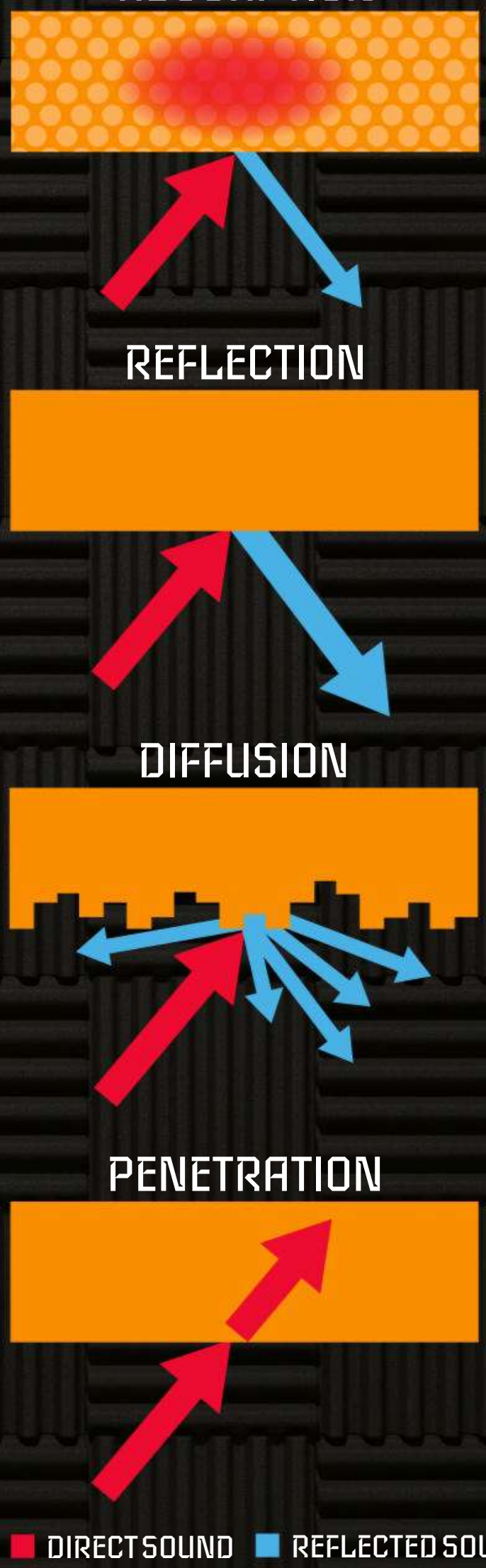
When sound waves travel through the air of your home, they will eventually hit something and react in several ways. The waves will either bounce off a surface like a wall, become absorbed or travel through it by causing it to vibrate and emit more sound waves on the other side. That is, of course, unless you've installed a series of soundproof panels that cut the sound waves short. As a surefire way to stop sound from leaking in and out of a room, soundproof panels can remove airborne sound waves and reduce excessive reverberation. Many of these panels are made from materials such as wool, carbon fibre or plastic, which absorb sound waves through their porous structures. To achieve a good barrier against sound waves, it's generally understood that covering around 30 to 40 per cent of a wall's surface area is enough to make a sustainable reduction in sound volume. However, to tackle the sound of impact noise, such as footsteps, underfloor soundproofing is used. Rubber is dense enough that it can absorb sound waves and reduce their volume.

Soundproofing is often used to dampen sound in commercial spaces such as restaurants and offices

The shape of the material also plays a part in silencing sound

SOUND AND SURFACES

How waves of vibrations interact with different surfaces



1 ABSORPTION
Materials with a low density, such as cork or foam, absorb the energy of sound waves and disperse them within.

2 REFLECTION
Sound waves bounce off the surface of these materials.

3 DIFFUSION
Irregular surfaces can break the energy of a sound wave into smaller, higher frequency portions.

4 PENETRATION
Without any soundproofing, the energy of the sound wave moves through a surface without being disturbed.

Did you know?

A typical conversation volume is 60 decibels

5 FACTS DIY SOUNDPROOFING METHODS

1 THICK CARPET AND RUGS
Carpets and rugs are a great way to absorb sound, especially pile rugs that have dense fibres to disperse vibrations.

2 BUILD BOOKCASES
Dense furniture such as bookcases and wardrobes are resistant to transmitting vibrations. Putting them against the walls can act as a sound barrier without the need for soundproof panelling.

3 SOFT FURNISHINGS
Soft materials such as blankets and curtains absorb sound waves and don't continue propagating the vibrations, whereas harder materials like wood or metal don't absorb waves as efficiently.

4 WEATHER STRIPPING
Weather stripping is a rubber or silicone material which is typically used around windows and doors to prevent leaks or air from entering the home. However, it can also be used to help stop unwanted sound waves from creeping into a room.

5 BUY HOUSEPLANTS
The leaves, stems and branches of many different house plant species can help absorb sound waves and reduce noise within a room. The larger the surface area of a plant's leaves, the greater the sound reduction.

© Alamy / Getty

THE SCIENCE OF CHOCOLATE

Each bite of this delicious confectionary contains a complex mixture of components that affect your body in many ways

WORDS EMMA DAVIES

Chocolate is a complex chemical delight containing over 500 individual flavour components, together with stimulants and a host of antioxidants. With that many ingredients, it's no surprise that crafting chocolate is a science in itself, requiring careful temperature control. For starters, cocoa butter has six different forms of crystals, all of which have different melting points. And the fat crystals in the final product have to be exactly the right type, size and shape for the flavour to be correct. This is achieved though tempering, a crucial stage of chocolate production that involves cooling so that crystals form before raising the temperature slightly to melt unstable crystals.

While we tend to think of chocolate as junk food, some of its components may actually be good for us. Cocoa beans are rich in organic chemicals called flavonoids. One particular flavonoid called epicatechin increases blood flow in the brain and disrupts the formation of the protein clumps that characterise conditions such as Alzheimer's. Research published in March 2014 also found that dark chocolate is used by bacteria in the stomach to produce anti-inflammatory compounds that are good for your heart. But so far, most studies suggesting health benefits for chocolate have been carried out on rodents, so further research would be required to see whether there are the same benefits in humans.

Did you know?

Fry's invented the chocolate bar in 1847

At the University of Bath, scientists have been studying rodent brain cells grown in the lab. "Our research has shown that epicatechin and related flavonoids have promising protective actions in brain cells," explains Dr Robert Williams, a neuroscientist at the university. "But whether we could achieve the levels required to replicate these effects in humans by eating chocolate is uncertain." The jury is still out on whether we can consider chocolate a health food. But since the positive ingredients are all found in cocoa itself, there's one rule of thumb – the darker, the better.

"We tend to think of chocolate as junk food, but some of its components may actually be good for us"

FOETUS FAVOURITE

Females prefer chocolate even in the womb – they may be more responsive to chocolate than males before birth, according to researchers at Marche Polytechnic University in Italy. They gave pregnant women chocolate to eat and then monitored the foetuses' heart rates and movements. Female foetuses responded more vigorously than males.

DID YOU KNOW? Côte d'Ivoire and Ghana in West Africa produce around 60 per cent of the world's cocoa

THE SWEET INGREDIENTS AND OUR BODY'S REACTION

What does it contain and how do these things affect us?

Cocoa is packed with several mood-affecting components. Some are stimulants, speeding up either mental or physical functions, while others are reputed to mimic 'feel-good' chemicals produced in our bodies. Cocoa is also rich in magnesium, and some research suggests that women who crave chocolate while suffering from premenstrual syndrome are actually deficient in this element.

1 CAFFEINE

Cocoa beans contain a small amount of caffeine, at concentrations of 0.2 to 0.4 per cent. A 40-gram bar of dark chocolate contains about six milligrams of caffeine, compared with an average 135 milligrams per cup of filter coffee.

2 THEOBROMINE

A mild stimulant that is structurally related to caffeine – both are plant alkaloids. This chemical contributes towards the bitter taste of cocoa. A cup of good-quality hot chocolate can contain 18 milligrams of theobromine, compared with two milligrams of caffeine.

3 FLAVANOLS

These chemical compounds can help blood flow, possibly by enhancing nitric oxide production in cells lining blood vessels. A review by the European Food Safety Authority suggests that daily consumption of ten grams of dark chocolate can help maintain vein dilation and blood flow.

4 TRYPTOPHAN

Chocolate contains high concentrations of this amino acid, used in the body to produce a feel-good neurotransmitter called serotonin. Too little serotonin may be associated with depression. Chocolate also contains serotonin-like chemicals called monoamines.

5 PHENYLETHYLAMINE

A chemical that is related to amphetamines, phenylethylamine is produced when we're in love and is sometimes known as the 'love drug'. This could help explain why some consider chocolate to be an aphrodisiac.

© Getty / Alamy

KNOW YOUR TRUE AGE

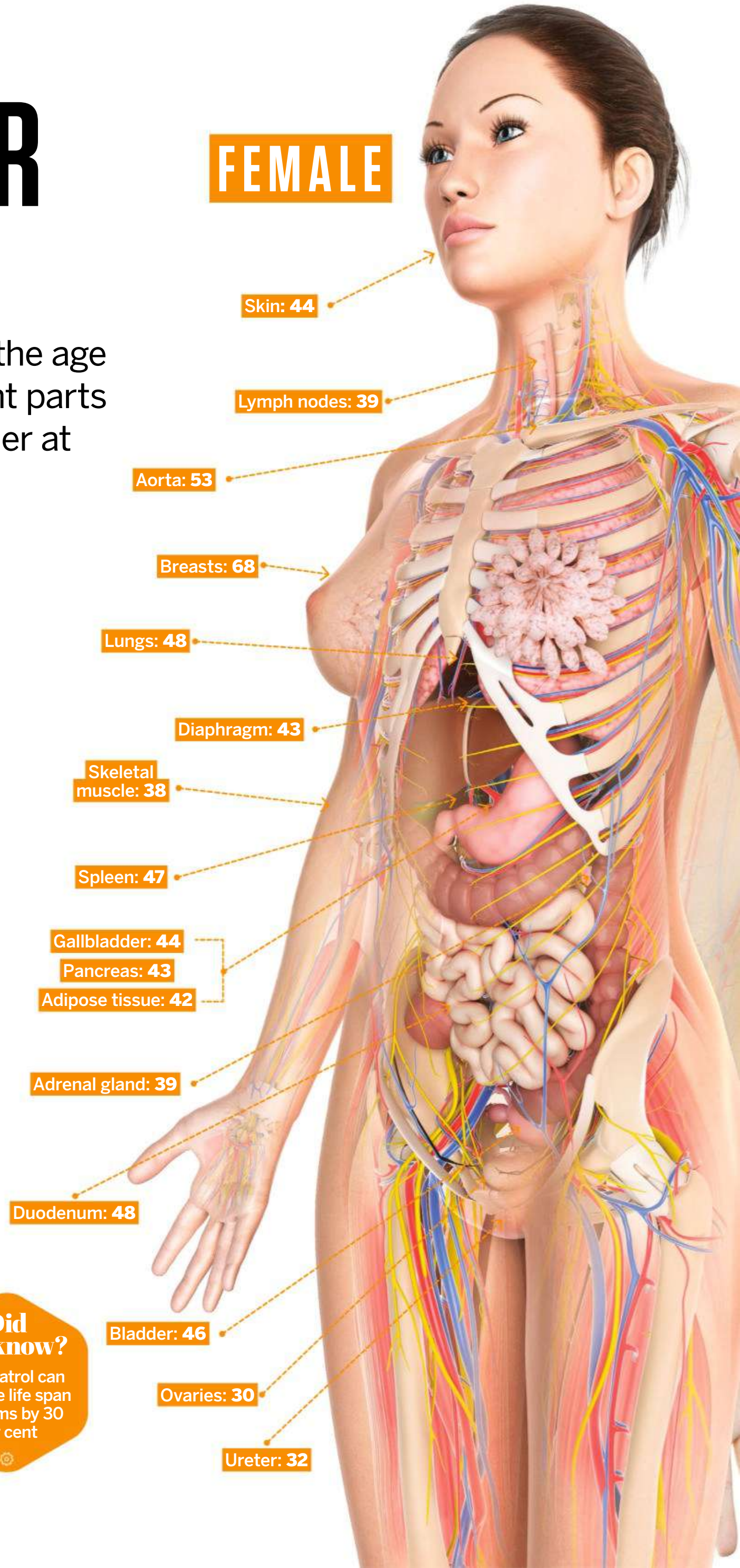
A technique for determining the age of tissues shows that different parts of our bodies are growing older at vastly different rates

WORDS **AMIT KATWALA**

You're only as old as you feel, the saying goes, but what if different parts of your body aged at different speeds? It turns out they do. A system for studying the age of our bodies has been developed, and it shows that different tissues inside us are effectively different ages. Scientists have used several systems before, such as the levels of hormones in our bodies, to study biological age. But in 2012 Professor Steve Horvath at the University of California, Los Angeles, looked at something new – DNA methylation, a naturally occurring process in which DNA is chemically changed over time.

Horvath analysed the DNA in 8,000 tissue samples from different parts of the body in different people to study these 'epigenetic markers'. What he found was striking – the amount of methylation in cells from most parts of the body were a good predictor of the person's age. But there were inconsistencies. Breast tissue, for instance, ages rapidly, whereas muscle ages slowly. The rates of ageing are also different in men and women."There are many medical implications, from cancer to premature ageing diseases," Horvath says. It has already been established that tissue that looks significantly younger or older could be cancerous. Horvath's study found that cancerous tissue has a biological age on average 36 years older than a subject's actual age.

Could this knowledge help us live longer? "If the epigenetic clock relates to a process that causes ageing, then it would be theoretically possible to slow down ageing by carefully targeting DNA methylation," says Horvath. But before scientists get to work meddling with methylation, they first needed to establish whether these changes were the cause of ageing or just a byproduct of another process. Now, a 2023 study from the University of Michigan has backed up Professor Horvath's findings. "Our main aim was... to see whether biological age acceleration as measured from DNA methylation was predictive of health outcomes and mortality," said research associate professor Jessica Faul. "It turned out that is largely the case. You can use certain DNA methylation markers to predict age and age-related outcomes quite well."



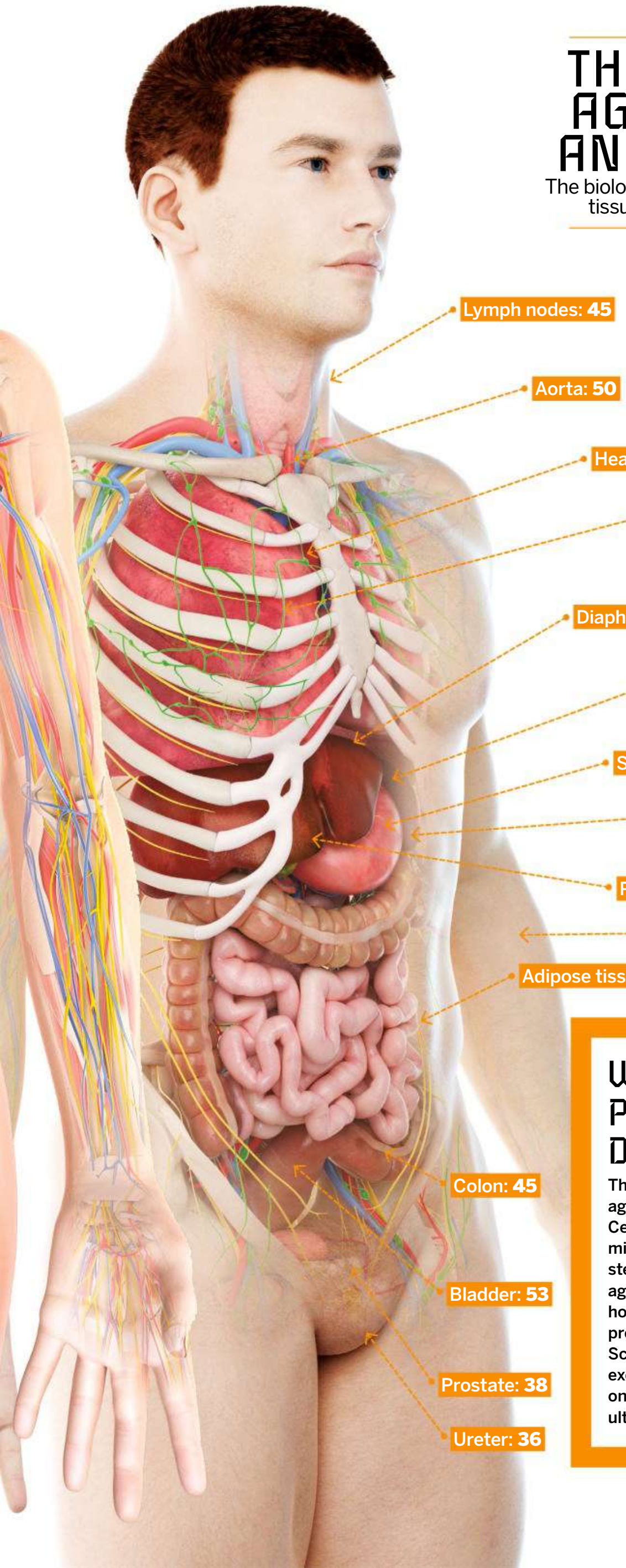
Did you know?

Resveratrol can increase life span in worms by 30 per cent

DID YOU KNOW? Jeanne Calment of France had the longest confirmed life span. She died in 1997 at the age of 122 years and 164 days

THE BODY'S AGE IN MEN AND WOMEN

The biological ages of two people's tissues in the 2012 study



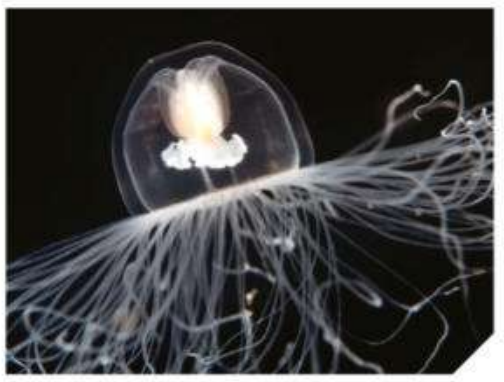
WHY OUR BODY PARTS AGE AT DIFFERENT RATES

There could be many reasons why ageing varies across the body. Certain organs, such as the heart, might rejuvenate themselves using stem cells. Breasts, meanwhile, may age rapidly because of the effects of hormones during puberty, pregnancy or menopause. Scientists aren't sure yet, but it's an exciting area for future study, and one that Horvath thinks could ultimately explain why we age.

THE OLDEST ANIMALS ON THE PLANET

MING THE MOLLUSC

507-year-old Ming, an ocean quahog clam, was the oldest animal ever discovered. When he was originally aged by researchers at Bangor University in Wales, he was thought to be 405 years old. But by counting his shell's outer growth rings, they discovered he was a century older.



IMMORTAL JELLYFISH

Turritopsis dohrnii is a small jellyfish that can transform back into a polyp in response to old age or its environment, equivalent to a butterfly reverting to a caterpillar. It happens by a process called cell transdifferentiation, and can continue indefinitely.

GIANT TORTOISES

These are probably the most famous examples of long-lived animals. The oldest, Adwaita, lived to 255 in a zoo in Kolkata, India, before dying of liver failure in 2006. Bigger animals tend to live longer, but giant tortoises likely owe their longevity to their slow metabolism.

© Getty / Alamy

HOW GRASS CHANGED LIFE

This tiny plant has influenced Earth's climate and the evolution of animals

WORDS AILSA HARVEY

Between 20 and 40 per cent of planet Earth is covered in grasslands, across every continent except for Antarctica. Grass is a low-growing, flowering plant with groups of narrow leaves growing from its base. The leaves of this plant are usually anchored to the soil by strong roots and grow together in large clusters.

One of the most common sights along stretches of grass is grazing animals. This is because many large herbivores rely on extensive grasslands to survive, and grass thrives with this regular trimming. The plants gain their energy from sunlight and require healthy cells to do so. If the leaves aren't cut, the tips die and start to rot. When they are damaged with a clean cut, however, the cells are triggered to grow quicker and produce new, healthy tissue. This is also why cutting your garden's lawn regularly can make your grass look thicker and healthier.

Did you know?

There are over 11,500 grass species

Humans rely on grass for food, too. Many grasses, such as maize or corn, are harvested as a staple part of some diets. Meanwhile, grass is used indirectly to produce food in the form of livestock. Cattle farmers require grass in their fields to feed cows and sheep before they are turned into meat for human consumption.

One of the most debated questions is how long ago grass evolved. Because grass doesn't preserve well as a fossil, a definitive answer is hard to come by. Until recently, many scientists estimated that grass began to grow on Earth between 50 and 65 million years ago. However, within the last decade a piece of 100-million-year-old amber was found that appeared to contain the oldest grass fossil to date. Studies of fossilised dinosaur faeces also suggest that some dinosaurs lived at the same time that grass grew on the planet, incorporating it into their diets.

PROTECTING THE PLANET

Grass is so widespread that it's easy to take it for granted. However, these plants are important for keeping our planet's ecosystems healthy. They cover and protect the soil underneath, limiting erosion from rain and harsh winds. Grass roots can reach up to 60 centimetres into soil, strengthening the ground and providing stability. Organic matter from grasses and grazing creatures encourages the growth of beneficial microorganisms, making soil healthier. Grass also removes some carbon dioxide from the atmosphere, absorbing it through the process that most plants use to produce energy: photosynthesis. This uses carbon dioxide, water and sunlight, so extensive plains of grass can help reduce the impact of global warming.

Grass roots grow deep before any shoot emerges from the soil

DID YOU KNOW? Bamboo is the largest variety of grass and can grow up to 45 metres tall

GLOBAL GRASSLANDS

How major grass habitats vary around the world

1 SAVANNAS

Savannas are usually found in tropical regions with distinct wet and dry seasons. The grasslands consist of tall grasses and scattered trees such as acacia and baobab trees.

2 PRAIRIES

These grasslands hold a variety of grass species and wildflowers. Prairie grasses experience moderate to low rainfall throughout the seasons.

3 STEPPES

Steppes have less rain than savannas. In these areas there are usually hot summers and cold winters, with short grasses.

4 THE LLANOS

Most of this area is treeless and covered with swamp grasses.

5 CAMPOS OF BRAZIL

This area has up to 4,000 large shrub and tree species, but in the last 30 years around a quarter of this grassland has been lost to human land use.

6 SUDAN SAVANNA

This is an extremely dry grassland with high temperatures. Tall elephant grass is common here, as are large mammals such as elephants.

7 SOUTH AFRICAN VELD

The soil here is quite thin, powdery and easily eroded. Red grasses and other drought-resistant species survive in this grassland at the southern tip of Africa.

8 AUSTRALIAN SAVANNA

This region is covered in dense grass and dispersed trees. Between May and October, the dry season causes intense wildfires, but many grass species here store nutrients underground and have fire-resistant roots for survival.

9 MIDWESTERN US AND CANADA PRAIRIE

Some of the most common grass species growing here include spear grass, wheat grass and blue grama grass.

10 PAMPAS OF ARGENTINA, URUGUAY AND BRAZIL

Over the last century, these plains have been used for grape-growing, producing half of South America's wines. Native grasses include Stipa, Piptochaetium, Aristida, Melica, Briza, Bromus, Eragrostis and Poa.

11 PLAINS OF HUNGARY, ROMANIA AND HISTORIC YUGOSLAVIA

This grassland covers flat and rolling plains. Much of the area is treeless and is used to breed cattle.

12 BLACK EARTH BELT OF RUSSIA

The black-coloured soil of this plain is made of decomposed plants. This makes it very fertile, with high phosphorus and ammonia levels.

13 MANCHURIAN PLAIN

This area is abundant in medium and tall grasses like feather grass and sheep's fescue.

14 GREAT PLAINS OF NORTH AMERICA

These are some of the world's largest remaining intact grasslands. There are about 450 grass species here.

15 KAZAKH STEPPE

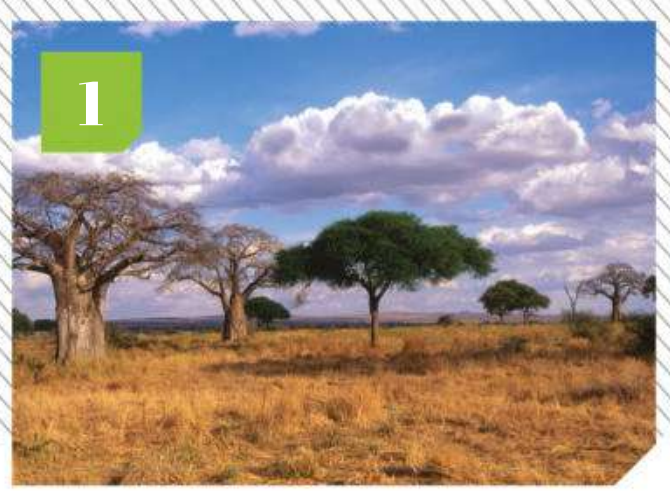
The grasses here have evolved to survive in droughts, fires, strong winds and grazing.

16 AUSTRALIAN STEPPE

Australia has a subtropical steppe near the dry deserts around the Musgrave ranges.

17 SUDAN STEPPE

The Sudan steppe lies further from the equator than the neighbouring savanna. It's more sheltered and gets more evenly scattered rainfall.



© Getty / Alamy

HOW DID GRASS EVOLVE?

Earth's soft grass coating has developed over billions of years

8 25 MILLION YEARS AGO
Grass first existed as widespread grasslands around 25 million years ago. The plant evolved to grow from the base rather than the tip so that it could survive animal grazing.

Did you know?
The grass genus *Festuca* makes up most UK lawns

2 2.6 BILLION YEARS AGO
Cyanobacteria evolved. This type of bacteria released oxygen, which altered Earth's atmospheric composition and enabled future life to exist.

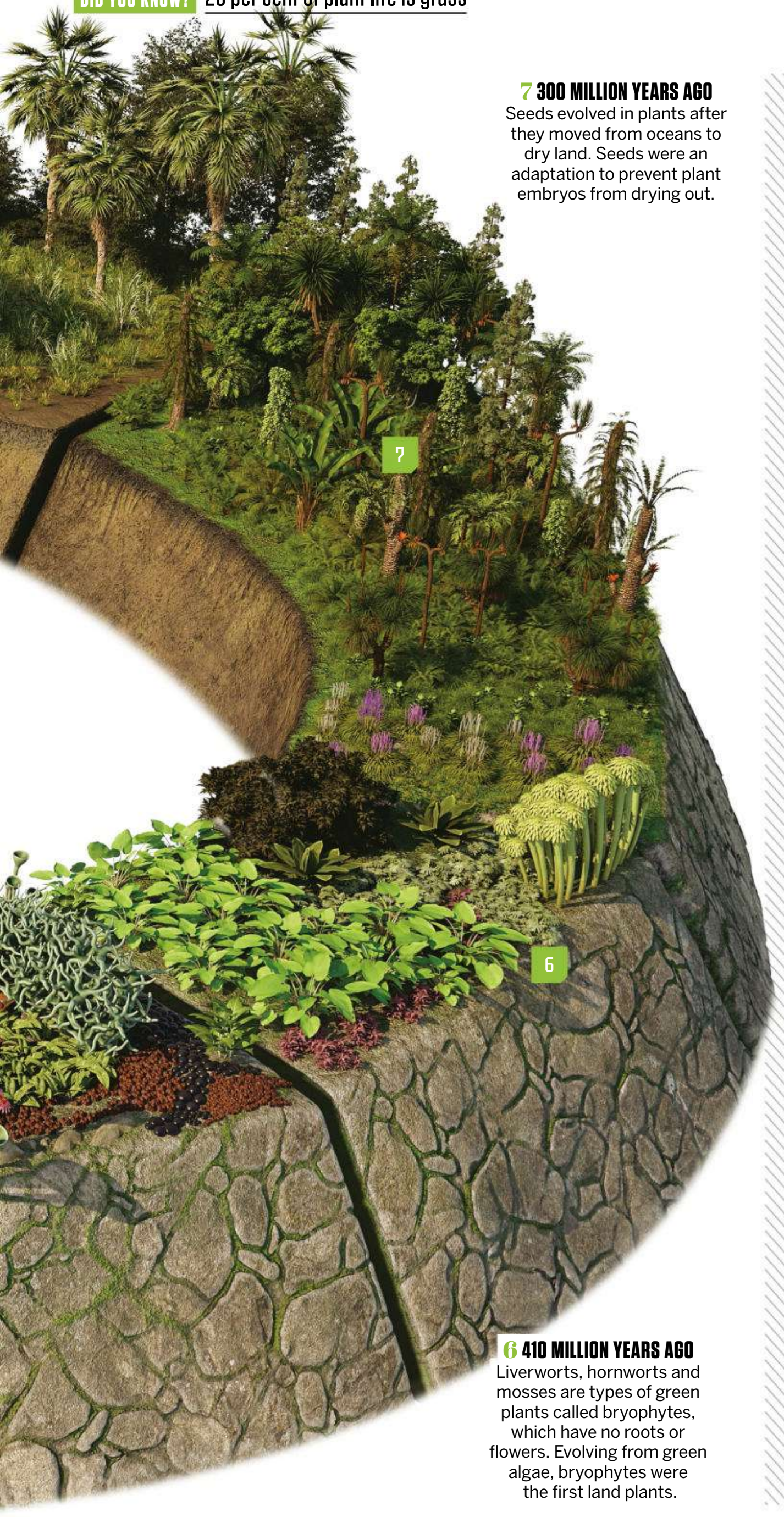
1 3.5 BILLION YEARS AGO
The first bacteria on Earth emerged. They were among the first life forms to exist.

3 2.4 BILLION YEARS AGO
Communities of living organisms in the soil, called biocrusts, emerged.

4 500 MILLION YEARS AGO
Grass cells are eukaryotic, meaning they have a nucleus and membrane-bound organelles. The first eukaryotic algae appeared in biocrusts half a billion years ago.

5 450 MILLION YEARS AGO
Lichens evolved when algae and fungi in the biocrusts combined. The fungus in lichens provides a protective structure and the algae carries out photosynthesis.

DID YOU KNOW? 26 per cent of plant life is grass



7 300 MILLION YEARS AGO
Seeds evolved in plants after they moved from oceans to dry land. Seeds were an adaptation to prevent plant embryos from drying out.

6 410 MILLION YEARS AGO
Liverworts, hornworts and mosses are types of green plants called bryophytes, which have no roots or flowers. Evolving from green algae, bryophytes were the first land plants.

SHAPING ANIMAL LIFE

CELLULOSE-DIGESTING STOMACHS
The stomachs of grass-eating animals contain bacteria that digest the cellulose in grass, breaking it down into sugars.

GRAZING TEETH
Grazing animals, like cows and sheep, have long-lasting teeth to grind on rough grass. The enamel extends past the gumline.

BIPEDAL PEOPLE
When savanna grasslands increased and replaced forests, humans evolved to walk upright. This made travelling and foraging much easier.

HOOFED FEET
Horses and other animals evolved to have hard coverings on their feet called hooves. Hooves help animals run faster and farther on open grasslands.

BURROWING HABITS
Animals such as prairie dogs and wombats developed digging and burrowing techniques to create sheltered homes for themselves on open grasslands.

© Alamy / Illustration by Nicholas Forder

WHY COWS HAVE FOUR STOMACH CHAMBERS

Peer past a bovine's grinding teeth and into its unusual digestive system

WORDS SCOTT DUTFIELD

Every day, cows (*Bos taurus*) eat around two per cent of their body weight – around 11 kilograms – in vegetation. Their diet naturally consists of fibrous grasses, legumes and hay, as well as the occasional piece of fruit. As a food source, grass is incredibly difficult to extract nutrition from. Simple stomachs, such as those of humans or canines, aren't able to digest it, whereas animals called ruminants, such as cattle, sheep and deer, have evolved a complex stomach system that can.

The journey through the bovine digestive system starts with the mouth, designed to puree plants as opposed to tearing through meat. Unlike the pointed teeth of the world's carnivores and omnivores, a cow's bottom jaw is lined exclusively with flat incisors and molars to grind down clumps of grass – which have already been torn up by its tongue – against the leathery layer that makes up the top jaw, called a dental pad. During mastication, or chewing, cows move their jaws from side to side to pulverise grass into tiny pieces for easier digestion. Once ingested, the chewed grass makes its way down the oesophagus and through a network of stomach chambers collectively known as the ruminant digestive system. Unlike what you may have heard, cows do not have four individual stomachs to digest their food. Instead their stomachs are made up of four distinct chambers that food passes through, releasing more and more nutrients as it goes.

Did you know?

Dairy cows produce around 36 kilograms of manure daily

The largest part of a cow's digestive system, called the rumen, acts as the body's food processor and fermentor, where countless helpful bacteria partially break down the organic matter. The partly digested grass, known as cud, then moves into another chamber of the stomach called the reticulum before being 'unswallowed' and sent back to the mouth. Cows then 'chew the cud' in a process called rumination to further break it down. The cud is once again swallowed and enters the third and fourth stomach chambers, called the omasum and abomasum respectively, for further digestion before passing through the cow's intestines and being released through the anus as a cowpat.

1 MOUTH
Grass is initially chewed, swallowed and then rechewed, or ruminated, after passing through the rumen and reticulum.

The red algae additive may help tackle cows' methane problem

CLIMATE-CHANGING BURPS

Food inside a cow's rumen is allowed to sit and ferment before it ruminates and is sent back through the digestive system. The byproduct of this is a greenhouse gas called methane. Each cow can produce around 120 kilograms of methane per year, which they emit predominantly through belching, as well as flatulating (burping and farting). Methane, like carbon dioxide, traps heat within the atmosphere, which contributes to increasing global temperatures. Farmers and scientists are working to reduce the production of harmful livestock methane, including the use of methane-reducing food additives. For example, research has found that adding ingredients such as red algae to cattle feed can reduce livestock emissions by around 65 per cent. Red algae (*Asparagopsis taxiformis*) contains an organic compound called bromofrom that inhibits the formation of methane while food is fermenting in the rumen. However, there are concerns over high levels of bromoform in meat and milk and its negative implications on human health.

DID YOU KNOW? Ruminant animals account for almost 80 per cent of the world's greenhouse gas emissions from livestock

FLYING COWS

There are many different ruminant mammals, such as giraffes, camels and antelope, but only a handful of birds share a cow's way of eating. The first birds that were found to digest food in this way were hoatzin (*Opisthocomus hoazin*), prehistoric-looking chicken-sized birds that can be found in the treetops of South American swamps. These birds forage exclusively on leaves that are fermented in the bird's foregut, which accounts for around nine per cent of their total body mass. Unlike cows, hoatzin don't regurgitate their meals to 'chew the cud'. Their serrated beaks are used to initially 'chew' their food before it's swallowed.

Hoatzin are often known as 'stink birds' for their fermented manure aroma

2 RUMEN
The largest chamber of a cow's stomach, which can hold around 95 litres of material. The rumen acts as the holding area of food, as well as a fermentation vat.

4 OMASUM
Often referred to as the 'butcher bible' because of its page-like folds of tissue, water and some nutrients are absorbed in this chamber, which also works as a pump to move food to the abomasum.

8 ANUS
Undigested food is packed in the large intestine and passed through the anus.

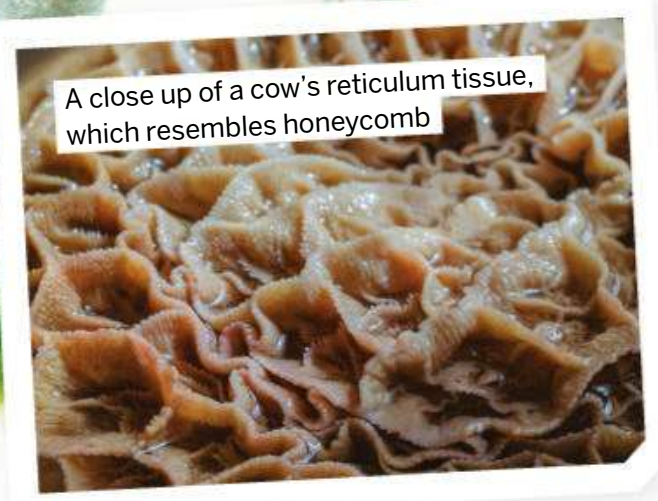
7 LARGE INTESTINE
The large intestine is the final site of digestion, where microbes make a last-ditch effort to metabolise the remaining digestible parts of grass.

3 RETICULUM
A pocket of honeycomb-like stomach where dense foods are broken down and inedible objects are held, preventing them from moving through the digestive system.

INSIDE THE RUMINANT STOMACH
Follow the journey of a cow's meal

6 SMALL INTESTINE
Around 20 times the length of the cow, the small intestine carries out the majority of food digestion with the help of secretions from the neighbouring pancreas and gallbladder.

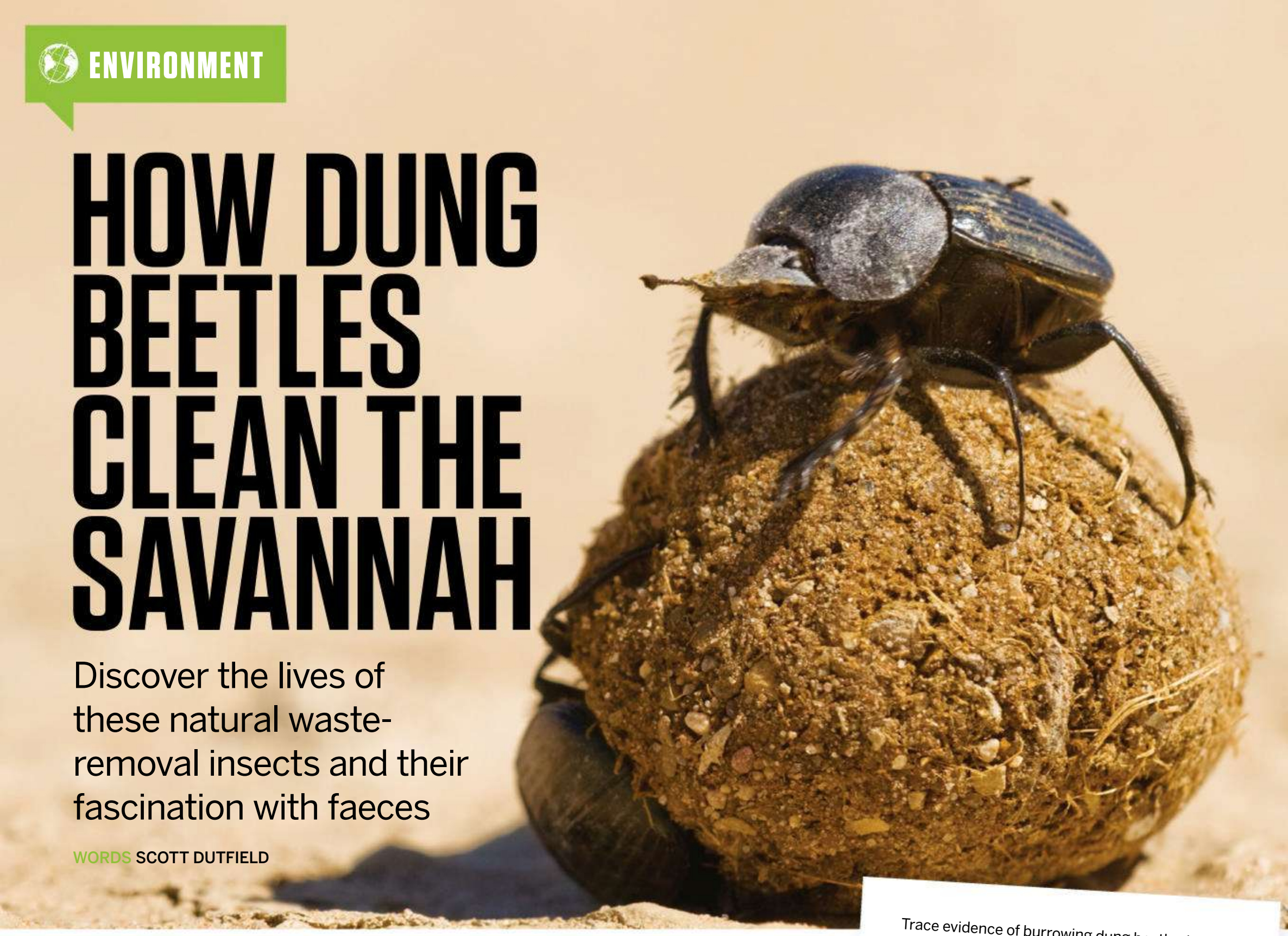
5 ABOMASUM
Hydrochloric acid and digestive enzymes in the abomasum work in a similar way to the human stomach, breaking down food and releasing nutrients.



A close up of a cow's reticulum tissue, which resembles honeycomb

© Getty / Alamy

HOW DUNG BEETLES CLEAN THE SAVANNAH



Discover the lives of these natural waste-removal insects and their fascination with faeces

WORDS **SCOTT DUTFIELD**

On a nice sunny day, there's nothing a dung beetle likes to do more than seek out some animal faeces, ball it up and roll it away for suppertime. With a pair of poop-sensitive antennae on their heads, dung beetles use their keen sense of smell to locate and track down faeces. Like many other coprophagic critters, such as rodents and rabbits, dung beetles obtain nutrition from the unmetabolised nutrients that remain in other animals' faeces. Scientists have even found that some dung beetles have a preference for faeces rich in nitrogen, which they use to build muscle-making proteins. They also prefer the dung of omnivores for its more pungent aroma compared to herbivore dung. It's a competitive business: more than 80 species of dung beetles can find themselves fighting over the same meal, so finding food fast is essential to their survival.

For some of the 600 species of dung beetles on Earth, encountering a mound of dung prompts them to create spheres of faeces that are then rolled away to underground chambers to feast on later. To help them find their way back to their underground homes, dung beetles use the Sun's position in the sky for guidance. Similarly, some nocturnal species, such as *Scarabaeus zambesianus*, use moonlight to orient themselves. Beetles can roll their dung balls for up to 200 metres using their hind legs while facing the ground and moving backwards. However, the roller beetles are in the minority. The majority of dung beetles either bury their loot or pile it up to make a faeces pool to dwell in.

The faecal remains of other animals aren't just an all-you-can-eat buffet for these insects

Trace evidence of burrowing dung beetles has been found in fossilised faeces called coprolite

DINING ON DINO POOP

Dung beetles first evolved around 115 to 130 million years ago. Using DNA sequence data, an international team of researchers discovered that their evolution correlated with the diversification and dominance of flowering plants called angiosperms. During this time period, angiosperms had become part of the diet of herbivorous and omnivorous dinosaurs, which likely produced the first source of palatable dung for early beetles. Fossilised dinosaur faeces from around 70 million years ago show trace evidence of dung beetle tunnelling while they ate. Around 66 million years ago during the Cretaceous-Paleogene extinction event that wiped out the dinosaurs, some dung beetle groups were made extinct because they lost their food sources. But some dung beetles had already diversified their appetites to include the dung of early mammals, which ultimately ensured their survival.

DID YOU KNOW? The ancient Egyptians believed that dung beetles were responsible for the Sun's movements

FAECES FREIGHT

Where does all the dung go?

1 ROLLERS

When one of these dung beetles locates dung, they use their shovel-shaped heads to begin shaping the dung into a ball. Once it's formed, they roll it randomly around the dung pile to gather more faeces until it is built into a ball that can weigh up to 50 times the dung beetle's weight. The rollers then move their ball many metres away from the pile and bury it.

Did you know?

There are over 60 species of dung beetles in the UK

2 TUNNELLERS

Wasting no time, these beetles get straight to work digging burrows and nests directly below the dung pile. They use their six legs to break ground and mine small chambers before using their front two legs to cut off pieces of dung to fill them with.

3 DWELLERS

Living life on top of the pile, these dung beetles don't spend any time balling up dung or digging burrows. They just roll around in muck and eat the dung around them. Females will lay their eggs straight in the dung pile, where the larvae will emerge, grow and lay their own eggs until it's time to find a new pile and repeat the cycle.

– they are also utilised as a nursery to raise their young. After mating, dung beetles will lay their eggs within the faeces, which the larvae will eat as they emerge. Some dung beetle mothers will also construct brooding balls, with a spherical mixture of faeces, eggs and saliva, to house their young.

Dung beetles also serve an important role in the wider ecosystem. Along with clearing up dung, their waste-management habits help control fly populations, as well as improve the nutrients that enter soil systems when the beetles bury dung.

A dung beetle larvae eating its way through a dung ball

ALTERNATIVE DIET

Across the rainforest floors of Peru is a species of dung beetle that has turned its back on faeces and found a new food source: centipedes. *Deltochilum valgum* is an eight-millimetre-long nocturnal insect that has evolved a predatory lifestyle. When the beetle encounters its prey, it uses its serrated head to cut through the segments of the centipede's body and split it open. Once the insect is torn apart, the beetle eats the innards, which likely also contain faeces. But *D. valgum* isn't alone in its alternative appetite. Another dung beetle species called *Canthon virens*, found in Brazil, appears to enjoy the taste of leaf-cutter ant queens.

A specimen of the centipede-eating *Deltochilum valgum*

© Getty / Shutterstock / Wiki: Helena Maratheftis / Illustration by Nicholas Forder

WHAT IS SEA FOAM?

Ocean decay and pollution contribute to this frothy lining on Earth's oceans

WORDS SCOTT DUTFIELD

After a particularly wavy day, the sea is often left with a foamy residue covering its surface that sticks to the sandy shorelines. These frothy trimmings are usually organic marine matter that has been churned up by the waves. Making up this foam are particles of salts, fats, proteins, algae, plankton and bacteria that surround air bubbles to form a light, fluffy substance. The sea foam that collects along coastlines helps recycle the nutrients of the oceans. The organic matter that accumulates in the foam is easily transported by waves and wind onto the land. At the shoreline, microbes and bacteria decompose the contents of the foam and release the nutrients into the surrounding environment. These nutrients can help plants such as algae and seagrasses grow, which marine life feeds on. In controlled volumes, sea foam assists this nutrient cycle and improves the health of marine ecosystems.

Did you know?

Antarctica's Spume Island produces a lot of foam due to stormy seas

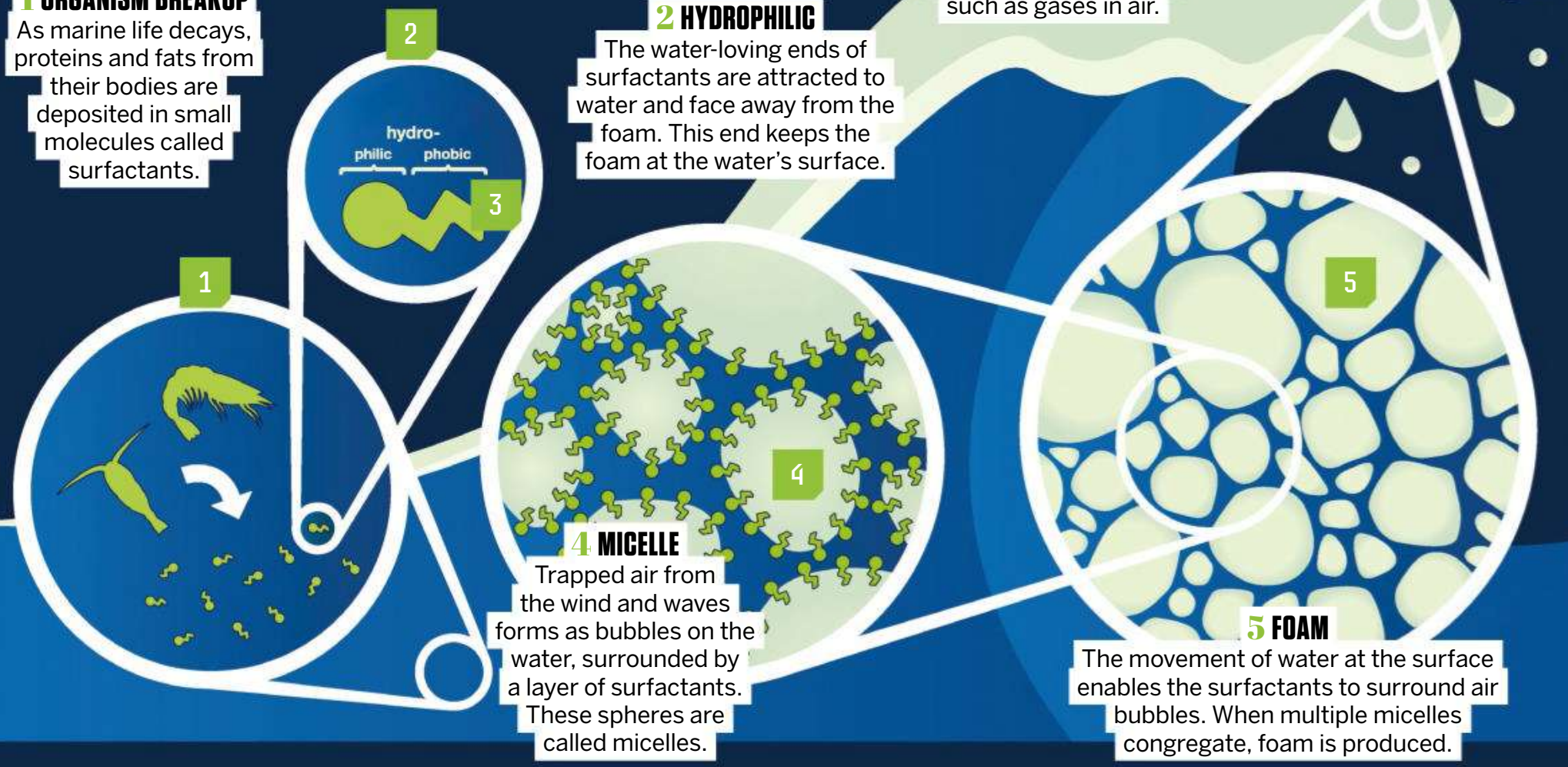
FOAM FORMATION

How does dead tissue produce this frothy consistency?

1 ORGANISM BREAKUP
As marine life decays, proteins and fats from their bodies are deposited in small molecules called surfactants.

2 HYDROPHILIC
The water-loving ends of surfactants are attracted to water and face away from the foam. This end keeps the foam at the water's surface.

3 HYDROPHOBIC
The water-fearing ends of the surfactant molecules surround molecules that don't dissolve in water, such as gases in air.



4 MICELLE
Trapped air from the wind and waves forms as bubbles on the water, surrounded by a layer of surfactants. These spheres are called micelles.

5 FOAM
The movement of water at the surface enables the surfactants to surround air bubbles. When multiple micelles congregate, foam is produced.

IS IT TOXIC?

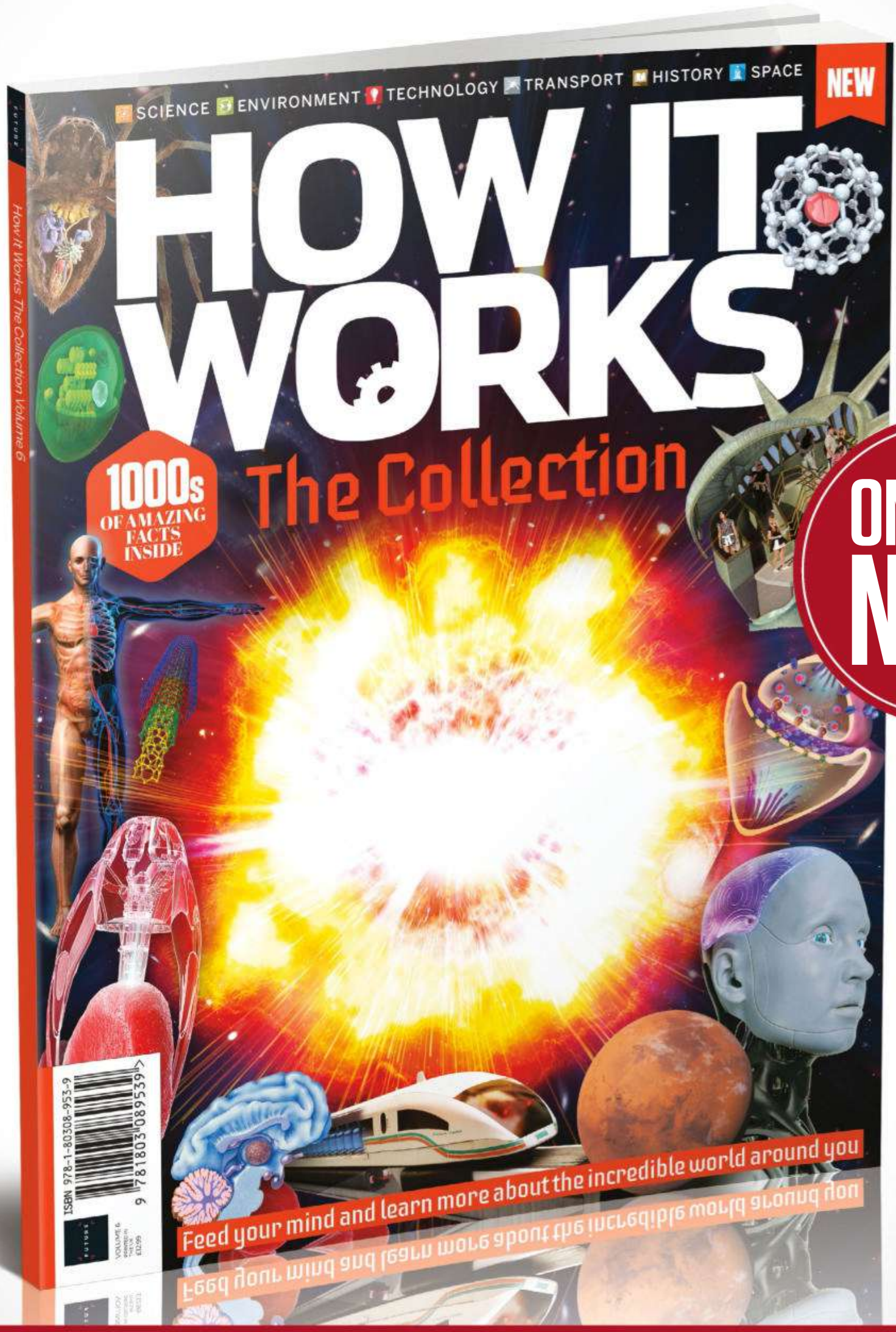
Sea foam is a natural dispersal of nutrients, and can provide a habitat for microscopic animals like amphipods and protective coverage for crustaceans. But too much foam can be toxic. Sometimes sea foam builds up following large algal blooms at the shoreline. The decaying algae release toxins when the foam bubbles pop, making them airborne and easy for humans and animals to inhale. Sea foam is likely to cause irritation in asthmatic people. When sea foam is produced from the release of pollution into the water, there can be oil, pesticides, sewage or other types of pollution in it. This type of sea foam is usually darker in colour and is much more detrimental to marine life when ingested.

Darker sea foam is more likely to contain pollutants

© Illustration: Kaleigh Ballantine/NOAA Office of Education / Alamy

FROM THE MAKERS OF HOW IT WORKS MAGAZINE, THE PLANET'S GREATEST COMPILATION OF FANTASTIC FACTS.

Find out what makes chillis spicy, see inside the Statue of Liberty, discover what's at the edge of space, why grass is green, how to train your pet, who invented chess - and much more.



ON SALE NOW

FUTURE

Ordering is easy. Go online at:

magazinesdirect.com

Or get it from selected supermarkets & newsagents

ANATOMY OF A SINKHOLE

Did you know?

Some sinkholes form in water, like Belize's Great Blue Hole

Sinkholes are cavernous pits that appear when the ground's surface collapses. How do these deadly depressions occur?

WORDS PROFESSOR IAIN STEWART

Florida is a US state collapsing in on itself. Amid the city streets, quiet suburbs and citrus groves, gateways are opening up into the real, hidden Florida. Virtually the whole of the Sunshine State, from the Keys in the south to the border with Georgia in the north, is underlain by a strange, cavernous underworld. That's because Florida is built on a vast platform of limestone bedrock. Just tens of metres below ground, a vast underground river system – the Floridan aquifer – channels billions of gallons of groundwater through subterranean passageways. This buried arterial network provides most of Florida's fresh water. It keeps the grass green, fills the many swimming pools and slakes the thirst of its residents. But the water is also eating away at Florida's soluble limestone foundations.

> "The water is eating away at Florida's limestone foundations. and that means the land above is sinkhole country"

And what that means is that the land above is sinkhole country.

Sinkholes mostly form by acid-tinged rainwater slowly eating away the limestone and washing soil and sediment into the cavities. The result is a pockmarked landscape of gentle pits and depressions that can flood to give residential estates much desired ornamental lakes. But some sinkholes form with the sudden collapse of the ground above caves and caverns. These 'cover-collapse' sinkholes are the deadly threats that lurk in the Florida subsurface. The trigger mechanism for these sinkhole trapdoors is still a mystery. Some are caused by too much water. Hurricanes can dump tonnes of water on the land over a matter of hours, weighing down the soil and collapsing the roofs of caves below. Others snap open from too little water. Drought years or groundwater pumping can reduce pressure in water-filled voids, causing unsupported sides to implode.

But the main reason for Florida's growing toll of sinkhole damage is ourselves. The lure of Florida sunshine is drawing ever more people to the state, and our urban sprawl is advancing into wild land primed with sinkhole traps. In the past they would have gone unnoticed... but not now.

OTHER SINKHOLES AROUND THE WORLD

GUATEMALA

Florida may be the sinkhole capital, but other places have their deadly equivalents. In 2010, a sinkhole killed at least 15 people in Guatemala City. It opened in the wake of Tropical Storm Agatha, occurring just three years after a similar sinkhole in the city in 2007 killed three people.

BOSNIA

Sinkholes are a common problem in Eastern Europe, where much of the landscape is underlain by soluble bedrock such as limestone. In November 2013, the residents of Sanica woke up to discover that an immense sinkhole had drained their village pond.

OMAN

Sinkholes aren't always traumatic. Bimmah Sinkhole in Bayt al-Afreet is often cited as one of the world's most beautiful sinkholes. It is a tourist attraction in its own right, as holidaymakers flock to swim in its emerald-green waters.

DID YOU KNOW? China's Xiaoxhai Tiankeng is the deepest sinkhole in the world at 660 metres

THE MENACE BENEATH FLORIDA

This 13.7-metre-deep sinkhole opened up beneath homes in Lake City in 2005 forcing evacuations

1

1 UNDERGROUND CAVES

As the limestone dissolves, pores and cracks appear, allowing more water in. This process hollows out the rock beneath, creating a large network of underground cavities. The land surface forms a bridge above these voids, and when it can no longer support its own weight it collapses in on itself, forming a sinkhole.

2

2 ROCK EROSION

The majority of sinkholes in Florida are caused by a layer of limestone rock lying beneath the soil across the entire state. This layer is extremely soluble, and acidic rainwater seeps through the soil until it reaches the limestone, eroding it over time.

3

3 UNPREDICTABLE HAZARD

It is difficult to predict when a sinkhole might open up due to numerous factors. Different soluble rock types behave differently and water can have varying degrees of acidity. This sinkhole opened up suddenly, and local authorities blamed large amounts of surface water dumped there at once by a hurricane.

4

4 WATER POOLS

Rain water pools at the bottom of a sinkhole, forming a shallow acidic pond of sorts that hastens the dissolution of the limestone below.

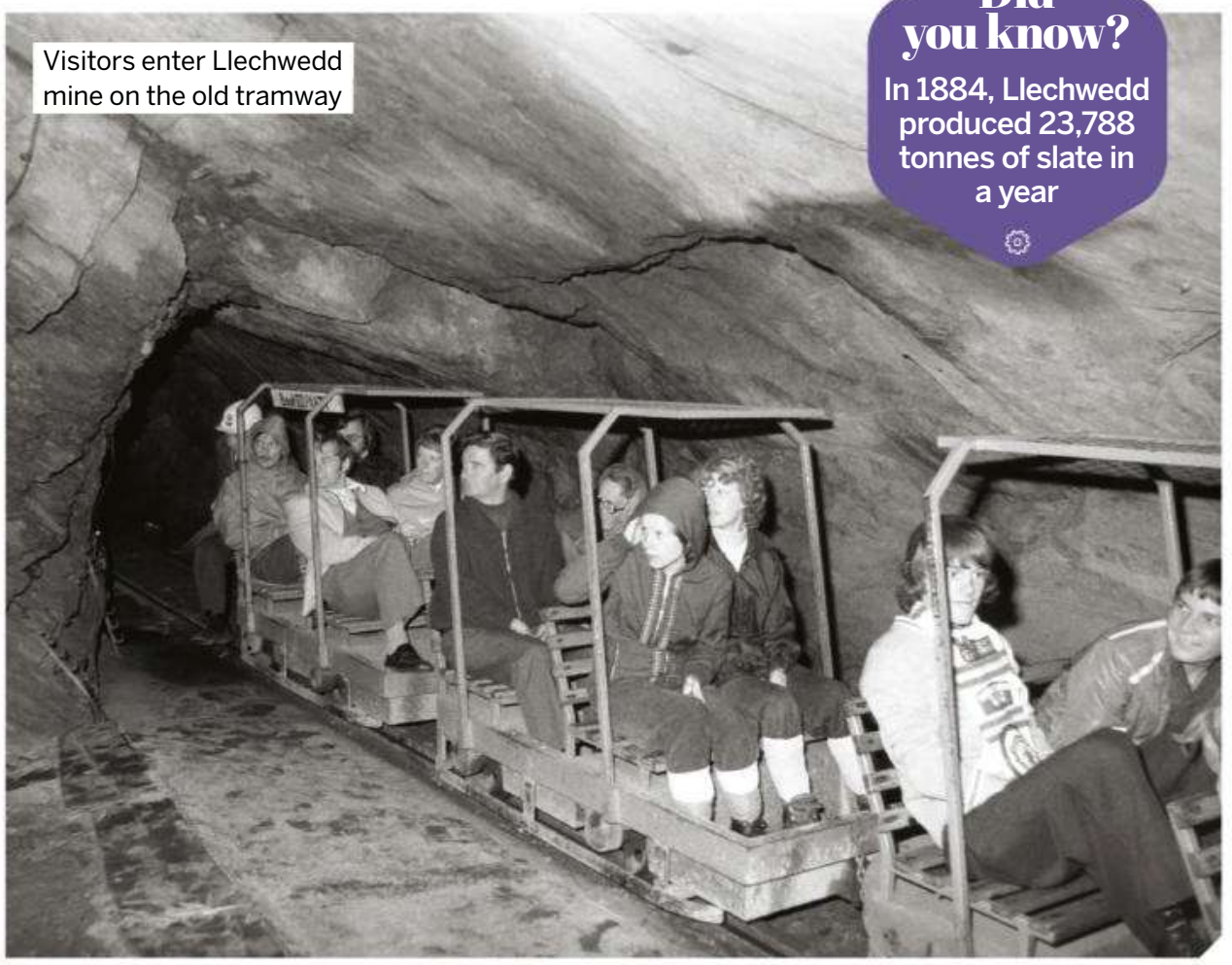
© Getty / Alamy

12 SECRET UNDERGROUND STRUCTURES

WORDS AILSA HARVEY

Discover the hidden worlds carved out of the ground across history

DID YOU KNOW? Petra is also known as the Rose City due to the colour the sandstone appears at sunset and sunrise



Visitors enter Llechwedd mine on the old tramway

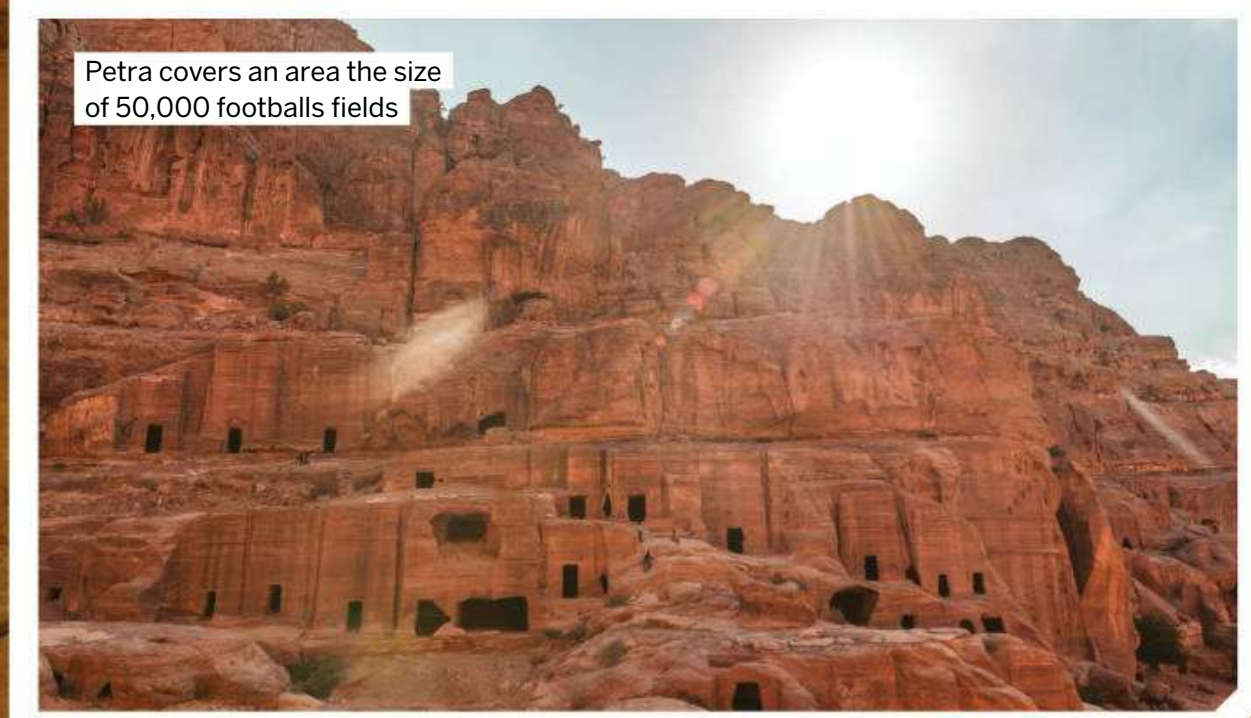
Did you know?

In 1884, Llechwedd produced 23,788 tonnes of slate in a year

DEEP MINE RAILWAY

To reach Llechwedd Deep Mine – over 150 metres beneath the rolling mountains of North Wales – you must travel on Europe's steepest cable railway. North Wales has been a slate-quarrying site for over 1,800 years; between 1846 and the 1980s, miners collected slate in this mountain pit, providing the roofs of buildings in the expanding towns and cities of the Industrial Revolution.

Miners spent long, bleak hours beneath the ground in Llechwedd's dark network of narrow tunnels and 250 quarry chambers. Its Deep Mine Railway opened in 1979, and it carries passengers down to the chambers at a gradient of 30 degrees. Visitors embark on this journey to explore the historic site. The steep passenger funicular is a high-tech replacement of the original transportation method used by miners. Workers of Llechwedd had to climb down ladders to reach the slate. From 1972 they were hauled on carriages through a newly built 61-centimetre-wide tramway by battery-powered electric vehicles.



Petra covers an area the size of 50,000 footballs fields

CAPITAL CITY CARVED FROM ROCK

Between 400 BCE and 106 CE, Petra in Jordan was the capital of the Nabataean Kingdom. The Nabataeans were an ancient Arabic tribe, 20,000 of whom lived in the cliff-carved city of Petra. Inside this sandstone metropolis is a hidden maze of monuments, tombs and intricate dwellings. Historians believe that only around 15 per cent of Petra has been uncovered by archaeologists so far, while 85 per cent of the city's contents remain a mystery, their secrets still buried deep underground.

The Petra community thrived, sheltered by the desert cliffs and situated along a main trade route between Arabia, Egypt and the Mediterranean Sea. Channels were carved into the city's walls to supply water to all corners of the city, while extra water was collected in cisterns to serve the Nabataeans during the drier seasons. In 363 CE the creatively carved city was largely destroyed by an earthquake. Many of the chambers were ruined, and the true extent of the city was lost in the sandstone for hundreds of years.

© Getty

INSIDE TURKEY'S ANCIENT CITY

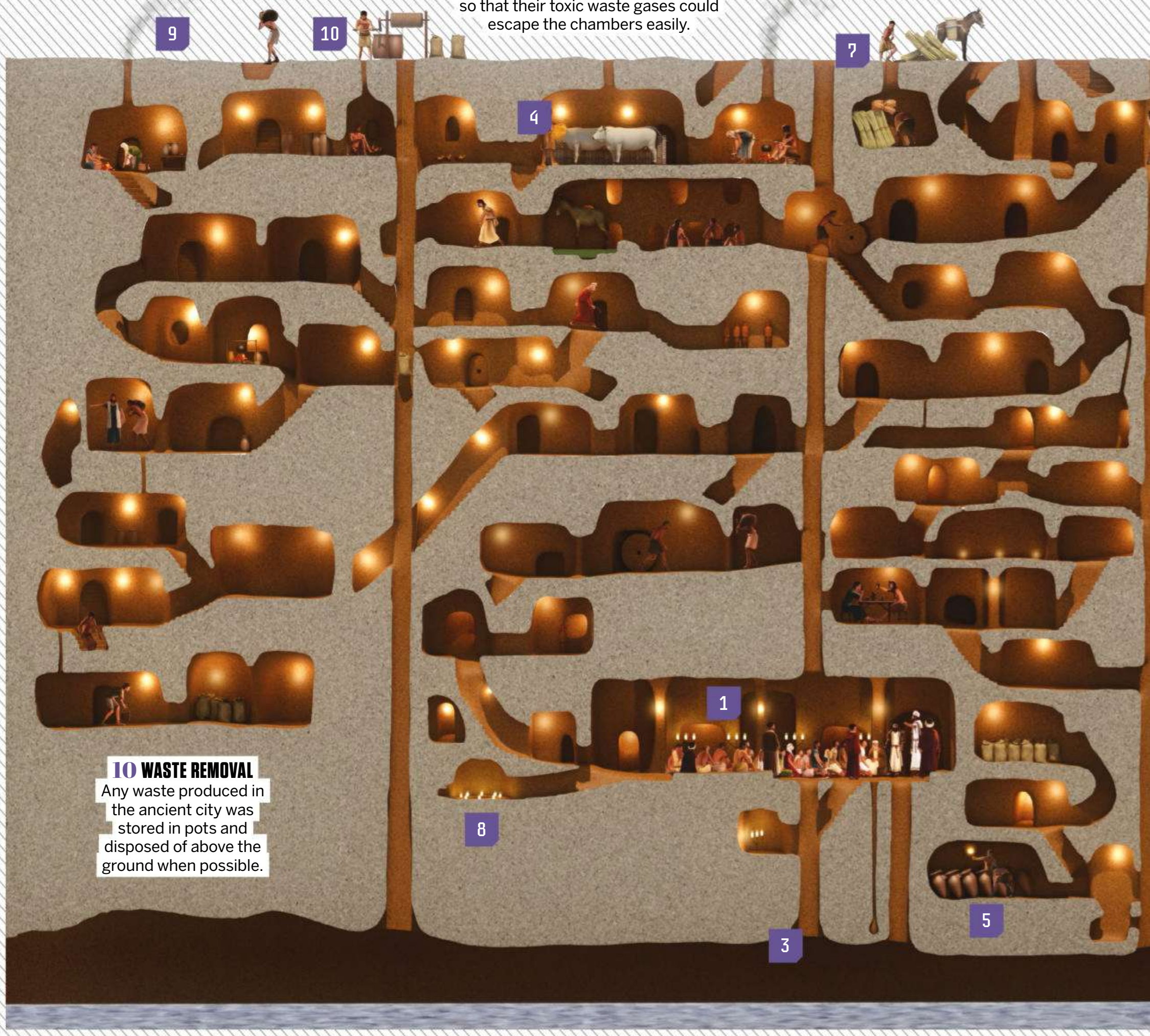
For 2,000 years, Derinkuyu was an active subterranean city, inhabited by 20,000 people and built over 85 metres into the earth

7 INCOMING SUPPLIES

The settlement was used by various groups – Hittites, Phrygians and Christians – who hid from enemy armies. They would stock up on supplies during periods of safety.

4 KEEPING CATTLE

Cattle were kept in stables near the surface so that their toxic waste gases could escape the chambers easily.



10 WASTE REMOVAL

Any waste produced in the ancient city was stored in pots and disposed of above the ground when possible.

1 WORSHIP IN THE EARTH

The church in Derinkuyu was one of the larger chambers. The long room had extensions to make it cross-shaped.

3 WATER COLLECTION

An underground river flowed underneath Derinkuyu. Deep wells were built throughout the city to scoop up fresh water.

5 STORAGE SECTION

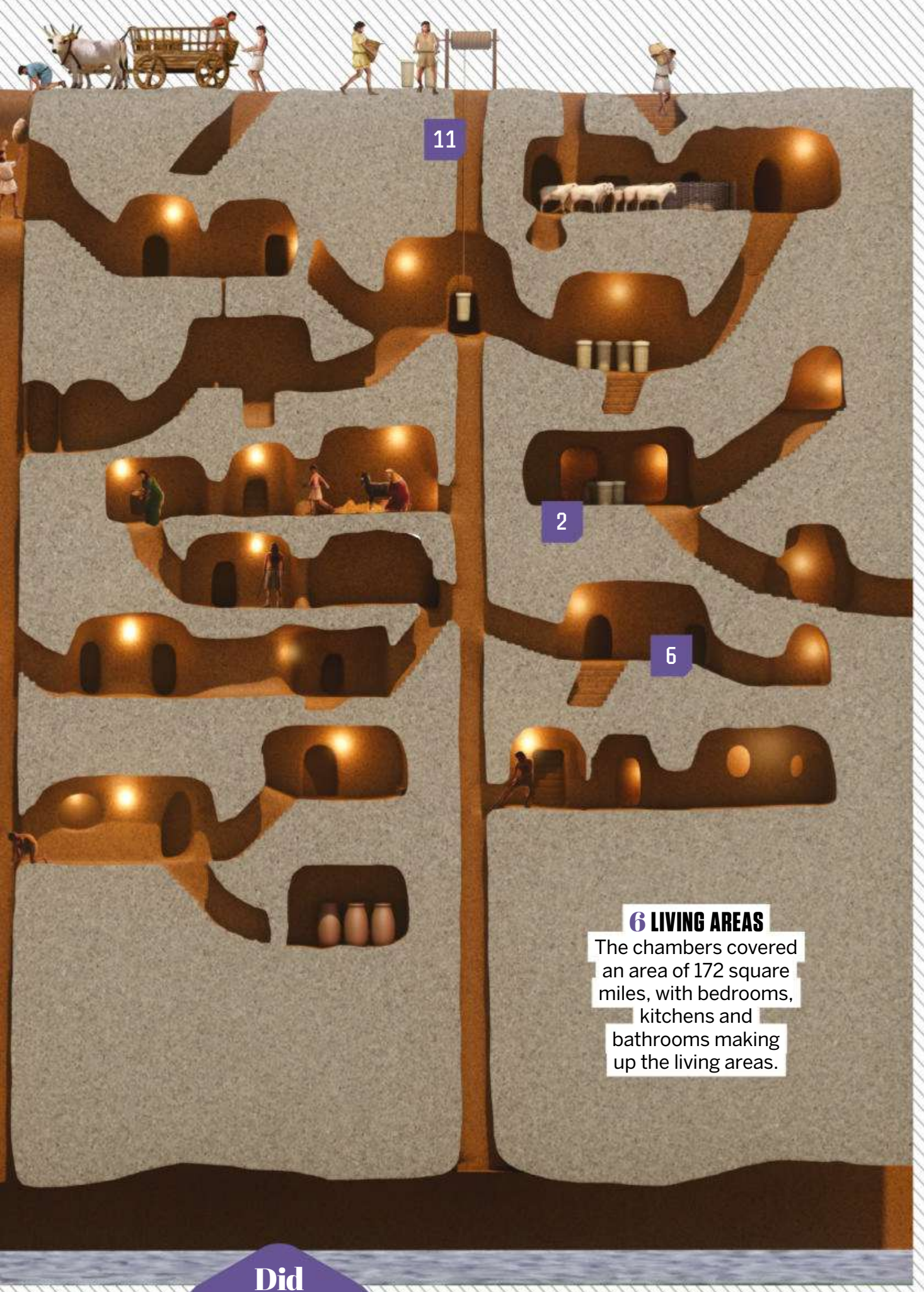
Large chambers throughout the city held the city's essential goods and materials, including dry food, tools and machines such as olive oil presses.

DID YOU KNOW? Derinkuyu translates to 'deep well' and is named after the water collection systems built into the city

8 BAPTISM POOL
Historians uncovered what appeared to be a baptism pool connected to the main worship chamber.

9 CHIMNEYS
Smoke produced by cooking or shaping metal tools was released from central chimneys.

11 VENTILATION SHAFTS
Over 50 ventilation shafts prevented suffocation and were used for communication between levels.



6 LIVING AREAS
The chambers covered an area of 172 square miles, with bedrooms, kitchens and bathrooms making up the living areas.

Did you know?
Stone doors in Derinkuyu weighed 500 kilograms

2 SAFETY STONES
1.5-metre-wide circular stone doors were rolled aside to open doorways. These could only be opened from the inside to prevent intrusion.

5 FACTS BUNKERS OF THE WORLD

1 SVALBARD SEED VAULT, NORWAY
This doomsday bunker is located on an island between Norway and the North Pole. Safely locked away inside are millions of seeds from 930,000 different crops. In the event of a global disaster, the vault ensures the plant species' survival to revive the planet's food supply.

2 GREENBRIER BUNKER, US
In 1955, the 34th US president, Dwight D. Eisenhower, ordered a bunker to be built below the Greenbrier Resort in West Virginia to house 535 members of Congress in the event of a nuclear strike.

3 BUNKER-42, RUSSIA
This nuclear strike shelter was designed for Soviet leader Joseph Stalin and lies 50 metres under Moscow. It was finished in 1956.

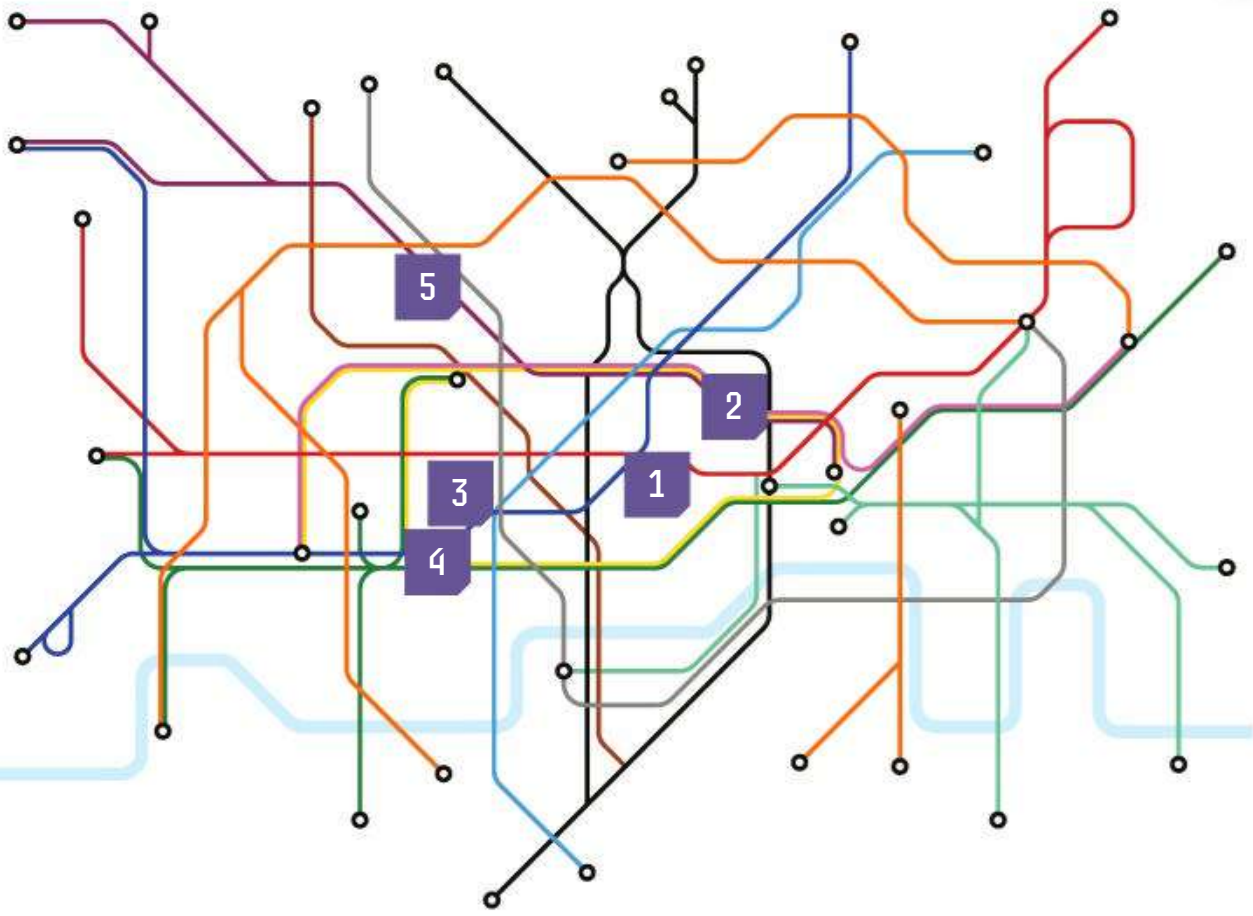
4 BURLINGTON BUNKER, ENGLAND
Beneath the market town of Corsham, Wiltshire, is a bomb, radiation and poison gas-proof city. It was built for 4,000 government members to live in in an emergency during the Cold War.

5 HOSPITAL IN THE ROCK, HUNGARY
An underground World War II hospital in Budapest was established in a natural cave in 1944. It was connected to St John's hospital by a secret passageway to access supplies and was one of the only safe spaces for an X-ray or operation during periods of bombing.

© Getty / Alamy / Illustration by: Adrian Mann

GHOST STATIONS OF THE LONDON UNDERGROUND

What became of these failed and abandoned platforms?



1 ALDWYCH

From 1907 to 1994, this station was part of the Piccadilly Line, but was closed when the number of passengers alighting here dropped. During the Blitz the station provided shelter to Londoners.

2 CITY ROAD

In 1922, City Road station was shut after 21 years running. Some of the heat produced by the underground tunnel is now used in a new energy centre at the station to heat surrounding homes.

3 DOWN STREET

Down Street station closed down in the 1930s and went on to house Winston Churchill during the World War II Blitz. The secret government headquarters was nicknamed The Burrow.

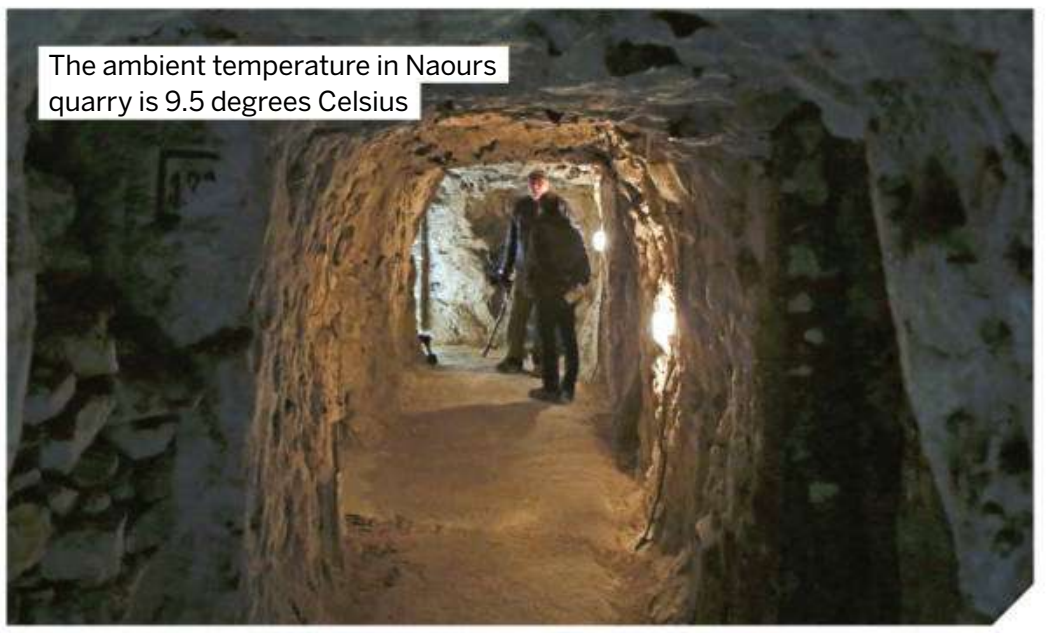
4 BROMPTON ROAD

This station was built too close to other stations on the Piccadilly Line, and was abandoned in 1934 after 28 years of service. It was later used as the government's secret command centre.

5 SWISS COTTAGE

This Metropolitan Line station opened in 1868, but just a few days later there was a head-on collision of two trains due to there being a single track. A new, deeper tunnel was built, but this ended up replacing the original line.

The Salt Cathedral of Zipaquirá is a Roman Catholic church



The ambient temperature in Naours quarry is 9.5 degrees Celsius

ZIPAQUIRÁ'S SALT CATHEDRAL

The city of Zipaquirá in central Colombia is home to a large salt deposit, making it a popular salt-mining location since around the 5th century BCE. The deposit formed 70 million years ago when an inland sea dried out and became buried by layers of earth and mud. 40 per cent of the country's salt exports still stem from Zipaquirá today. Perhaps one of the most mesmerising tourist attractions in the area is the mine's Salt Cathedral, which was built so miners had a place dedicated to reflection and prayer. This was essential when engaging in such a dangerous occupation as salt mining. Many prayer spaces were carved over the centuries, but the existing cathedral was opened in 1995. The cathedral is carved from 250,000 tonnes of salt and can be found 190 metres underground. Before entering the cathedral, visitors pass 14 salt chapels.

FRENCH QUARRY REFUGE

Slightly east of Naours village in northern France, a hiding place is concealed beneath the soft, woodland-covered limestone rock. The secret city was first carved by Romans in the 3rd century CE, and the end result was a matrix of 300 rooms and 28 galleries over 22 metres below the ground that 3,000 people could call home. The subterranean space had initially been used as a quarry, and later a city with town squares, bakeries and three chapels. During World War I, Allied forces discovered the space and used it as a hiding place. The same occurred in World War II when the Nazis claimed it. The sneaky engineering of the quarry made it an ideal hiding place: all chimneys were directed through cottages and other overground structures so that its existence couldn't be easily detected.

DID YOU KNOW? The Zipaquirá salt mine has an average temperature of 14 degrees Celsius

THE CU CHI TUNNELS

In the Vietnam War, Viet Cong troops dug these tunnels as safe routes during combat

1 BOOBY TRAPS
Punji bear traps were positioned near the Cu Chi tunnels. When the opposing American and South Vietnamese forces stepped on the traps, the floor would fall through and they would impale their feet on large spikes.

2 SMOKE VENT
Vents from the tunnels' kitchens were directed towards long grasses and the bases of trees to keep their location concealed.

3 WATER WELLS
Vertical holes were dug until water was reached for drinking. Wells were built in these holes to collect water regularly and easily.

4 STOLEN GOODS
Any clothes or weapons left above ground by American soldiers were taken by the Viet Cong. The clothes prevented enemy sniffer dogs from finding them.

5 LIVING AREA
Some of the hammocks in the living chambers were made using American parachutes.

6 MAKESHIFT HOSPITAL
The wounded were treated below ground level to prevent enemy forces reaching the most vulnerable.

7 MEETING ROOM
Mission plans were devised by officers in dedicated meeting rooms.

8 AMMUNITION STORAGE
Ammunition was stockpiled and stored in a lower level.

9 TUNNEL RATS
American soldiers with small frames would be tasked with breaking into the narrow, hand-dug tunnels. Booby traps were dispersed for these intruders, who were nicknamed tunnel rats.

Did you know?

Bicycle electricity generators were used in some Cu Chi tunnels

© Alamy / Shutterstock

BUILDING HADRIAN'S WALL

How the Roman Empire used artful engineering and widespread influence to forge this snaking wall across Britain

WORDS AILSA HARVEY

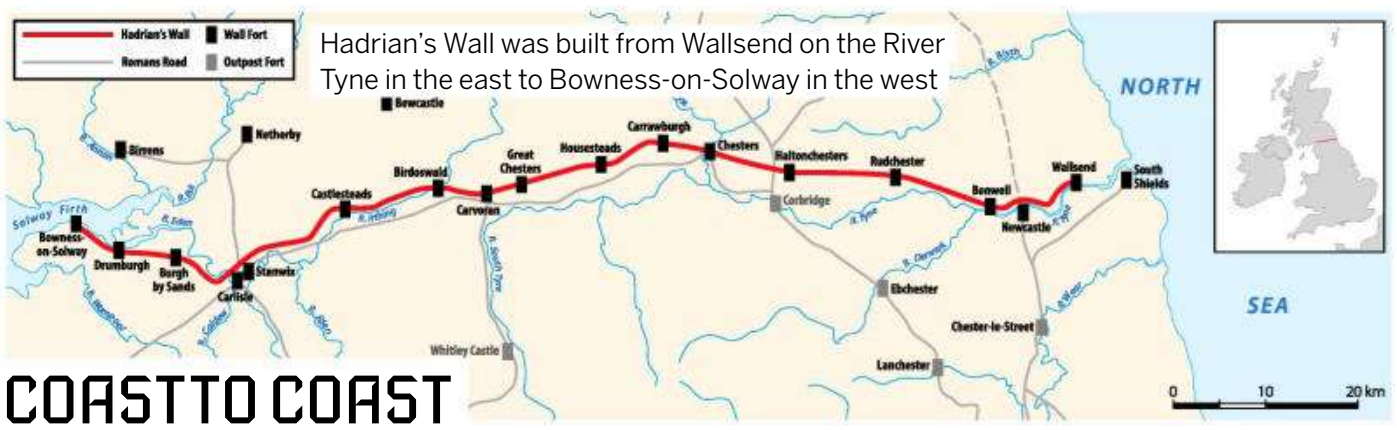
After its invasion of Britain in 43 CE, the Roman Empire continued to expand and conquer territory in the north. By 122 CE the empire ruled all of Britain except for Caledonia – a historical area covering most of modern-day Scotland – and northern England. To prevent further attacks from Caledonian warriors, referred to as barbarians by the Romans, Emperor Hadrian ordered the construction of a barrier to separate the territories and keep their conquered land safe. This would become known as Hadrian's Wall, and the main structure consisted of a 73-mile wall with 80 forts called milecastles, 17 larger forts called cohort castles and two lookout turrets per milecastle to ensure that the entire stretch was under surveillance at all times.

Did you know?

Ten per cent of the wall remains today

Milecastles were built roughly one Roman mile (0.92 miles) apart along the wall's length. The size of these forts varied, but most had an internal space of around 15 by 18 metres, with stone walls up to three metres thick, and were a similar height to the rest of the wall at around five metres. These protected spaces were used as base camps for the troops dispersed along the border.

Hadrian's Wall remained an active military base for around 300 years. Each of the large forts were military units, and each one was linked to a community camp in the nearby area called a vicus. When Hadrian's Wall was abandoned by the Romans, the stone was taken away by locals and used to build homes. Little of the wall remains today, but you can still see some of its base near the Scotland-England border.



Hadrian's Wall was built from Wallsend on the River Tyne in the east to Bowness-on-Solway in the west

COAST TO COAST

The wall spanned the width of the country, from the North Sea to the Irish Sea. This route crossed a narrow section of Britain, reducing the building materials, time and effort required, and construction was completed over several years. Plotting the route across the country meant that the landscape varied drastically. Steep, mountainous terrain was factored into building to work as extra barriers, while bridges and fords were built to cross rivers, and any quarries along the route were utilised for stone construction materials. Citizen-soldiers of the Roman army undertook this project, with troops from all three of Britain's legions. These were the South Wales-based II Augusta, York's VI Victrix legion and the XX Valeria Victrix from Chester.

DEFENSIVE ENGINEERING

Efforts to protect the land beyond Hadrian's Wall extended past the construction of the wall itself. On the northern side, the Romans dug a ditch to prevent attackers approaching the wall. The excavated earth was used to form a slight mound before the ditch, which served as an extra barrier. There was also a large ditch just south of the wall, called a Vallum, which was six metres wide and three metres deep. On either side of this ditch, which ran parallel to the wall, were two mounds, measuring two metres in height and six metres in width. Any secondary logistical purpose of this ditch is debated by historians, but if any invaders did break through the wall, the landscape on the other side of the construction meant they would have to enter the steep ditch and scale two mounds before engaging in a more serious assault. Finally, between the southern mounds and the wall there was a raised road called the Military Way. This was a route used to transport Roman troops quickly to different parts of the wall.

DID YOU KNOW? Over the course of six years, 15,000 men built Hadrian's Wall

WORKING IN THE WALL'S TURRETS

Positioned on either side of the milecastles were 158 turrets where soldiers were stationed

Some of the wall still stands

5 CRENELLATIONS

The tops of the turrets had a pattern of openings. The gaps were used to fire weapons through, while the taller sections protected the soldiers' bodies.

2 KEEPING WATCH

The soldiers in each turret took it in turns to keep watch for enemies over the surrounding landscape.

4 STONE CONSTRUCTION

The stone towers were built before the wall itself. This is shown by the remains of the shelters, which aren't bonded to the rest of the wall structure.

1 MULTISTOREY

Turrets were built with three or four storeys.

7 RUBBLE CORE

The stone walls were packed with smaller stones, gravel and mortar. This made the carrying weight for Roman builders more manageable and resulted in a strong, solid wall.

6 PARAPET

The side doors opened up onto a walkway along the wall, connecting the turrets and increasing the area of patrol.

3 TURRET LIVING

Soldiers who were on lookout duty would live in these simple constructions. The lower storeys were used for cooking and resting.

© Alamy / Shutterstock

How virtual and augmented reality technologies are being used in a sophisticated military training tool

WARGA

DID YOU KNOW? Project OdySSEy was also developed by the company Hadean Supercomputing

Did you know?

Project OdySSEy was launched in June 2022

TIMES

WORDS
AILSA HARVEY

Can anything prepare you for war? In the armed forces, military personnel train to use weapons, are educated on the impact of crucial decision-making and learn how to command large dispersed groups on the ground. Usually, all of these techniques are learned in tightly controlled conditions on secure military bases until the skills are put to use in life-or-death scenarios. But logistically, large-scale live training sessions in the real world are very limited compared to the scope of an actual battlefield. This is where virtual reality can be of help. Project OdySSEy is a virtual military training platform developed by aerospace company BAE Systems, combining expertise in data analytics, virtual reality (VR), augmented reality (AR) and supercomputing. The collaborative project means that military training can take place remotely from anywhere in the world.

Trainees can connect to the VR software from various military bases and can work and communicate with their allies to complete realistic missions in virtual worlds. This involves a trainee wearing and manipulating a variety of apparatus depending on the level of physical activity required in each person's role, ranging from vehicle-simulating machines for soldiers on the battlefield to mixed-reality headsets for battlefield commanders and a simple laptop for those who work in intelligence and cyber security roles. Forces working on land, sea and air missions train together, connected to a single synthetic environment which they can plug in to at any time and location.

Work in the armed forces can be high risk, so it's essential that all members are trained thoroughly and know how to act in risky situations when on a real mission. As well as providing an accessible space for training activities, the virtual worlds generated in these immersive headsets are a sandbox to experiment in. Somebody who is flying an aircraft through hazardous skies has the space to make mistakes in a safe environment and learn from the catastrophic impact of small errors. When faced with the same situation on a real mission, the pilot will have benefited from this testing and is more likely to navigate obstacles safely and successfully.

©BAE Systems

SIMULATED STRATEGY

How battlefield commanders direct a virtual mission using Project OdySSEy

Did you know?

Around 6,000 aircraft fly in the UK's skies every day

1 BATTLESPACE

Augmented-reality headsets project the same three-dimensional interactive battle map into the room for both commanders.

4 REAL-TIME LOCATION

As trainees in flight simulators control their vehicles in the virtual world, their movements are tracked here in real time and their flight path is recorded.

5 SOCIAL MEDIA FEEDS

Live social media updates are vital to modern warfare in documenting movements on the ground. The computer generates realistic posts about the battle zones that are being monitored.

6 REMOTE CONNECTIONS

Hundreds of soldiers in different locations can connect to one simulation. A soldier driving a vehicle is connected to a vehicle-specific VR device and receives commands from these trainees.

"The virtual worlds generated in these immersive headsets are a sandbox to experiment in"

DID YOU KNOW? Live training is still essential for pilots to experience the physiological impact of jet flight

5 FACTS MODERN MILITARY TRAINING METHODS

1 SMART COMPUTERS
Computers can be trained with data to 'think' like a human in a battlefield simulation. They can predict what impact their decisions will have, helping soldiers learn their most effective course of action.

2 WATER ESCAPE
Water-egress training involves escaping from mock-ups of aircraft pushed into swimming pools.

3 CYBER WARFARE
With security information stored as online data, armed forces provide simulated cyber-attack training. Participants need to strategise to defend their data.

4 NIGHT-VISION EQUIPMENT
Soldiers serve through day and night, so require training in night-vision technology. This includes goggles that enhance natural ambient light, thermal imaging cameras and infrared lasers.

5 HYPOXIC TRAINING
Altitude training sets soldiers up for work in high mountainous environments and aircraft. Masks that reduce their available oxygen enable this training to be conducted at any training base.

TRAINING BUDDIES

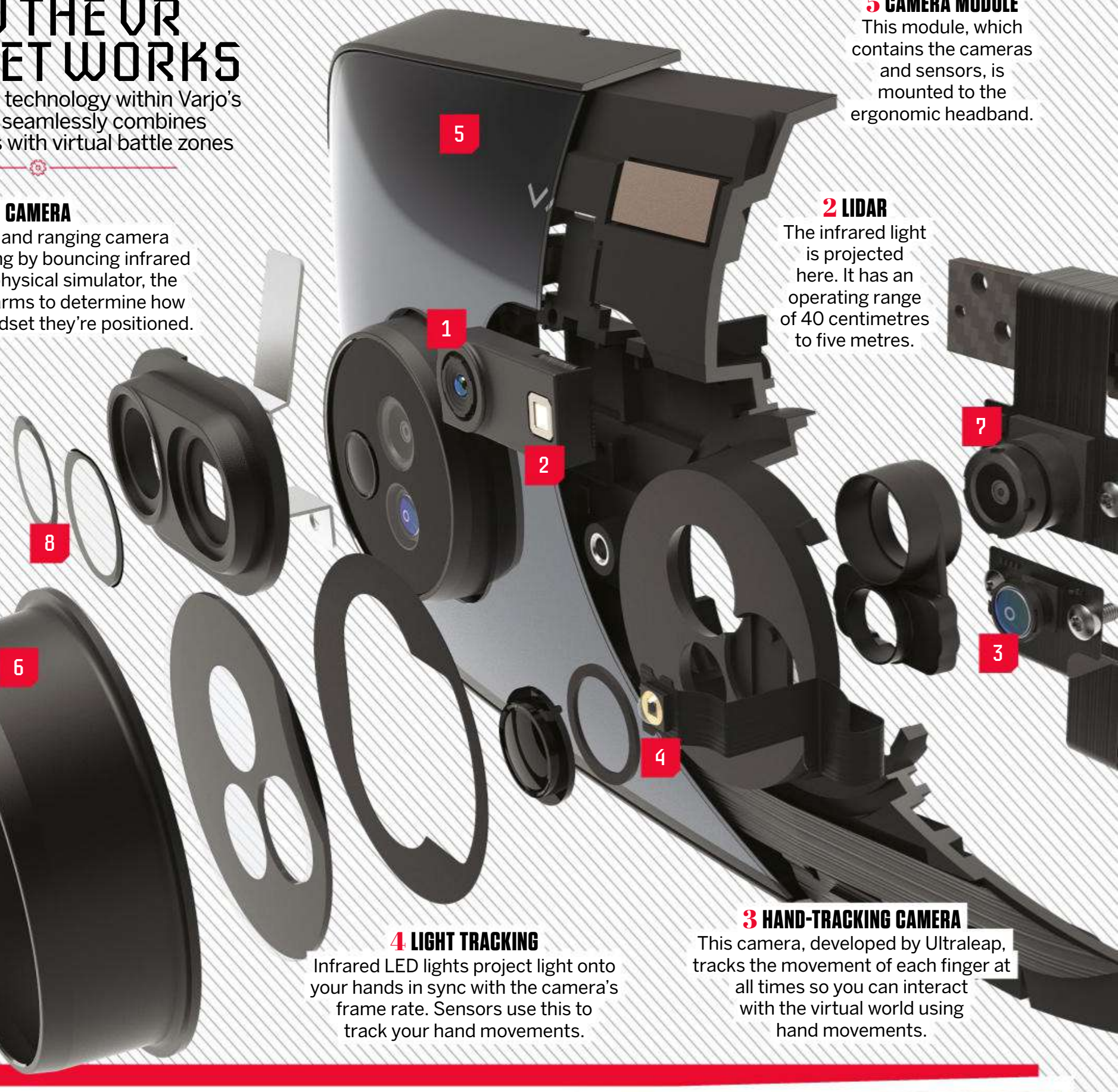
To increase military power and to assure mutual protection between countries, national armed forces ally themselves with others. These countries aren't necessarily close geographically, and that can make training as a single force problematic. The VR technology used in Project OdySSEy eliminates some of these issues by enabling invited personnel to join a training session from anywhere in the world. By connecting to a virtual-reality world, large groups of people can partake in regular joint training activities that would otherwise be difficult to organise. For countries like Australia, with multiple bases across a 2,485-mile-wide country, the technology can also be used to connect members of its own military. Travelling to engage in real-life training isn't replaced completely by simulation technology, but the evolution of this method means that militaries can unite as often as they wish to and with short notice.

A soldier could be training in a room alone, but is surrounded by other connected trainees in vehicles and on foot in the virtual battlefield

© BAE Systems

HOW THE VR HEADSET WORKS

The mixed-reality technology within Varjo's XR-3 headset seamlessly combines physical controls with virtual battle zones



1 LIDAR CAMERA

The light detection and ranging camera provides depth sensing by bouncing infrared light pulses off the physical simulator, the wearer's hands and arms to determine how far away from the headset they're positioned.

5 CAMERA MODULE

This module, which contains the cameras and sensors, is mounted to the ergonomic headband.

2 LIDAR

The infrared light is projected here. It has an operating range of 40 centimetres to five metres.

8 LIDAR MODULE WINDOW

The lidar's components are protected by optically coated glass. This is glass with anti-reflective properties to prevent interference with the laser.

6 BEZEL

The aluminium frame protects the cameras and sensors. It also gives cameras more space to achieve a wide field of view.

4 LIGHT TRACKING

Infrared LED lights project light onto your hands in sync with the camera's frame rate. Sensors use this to track your hand movements.

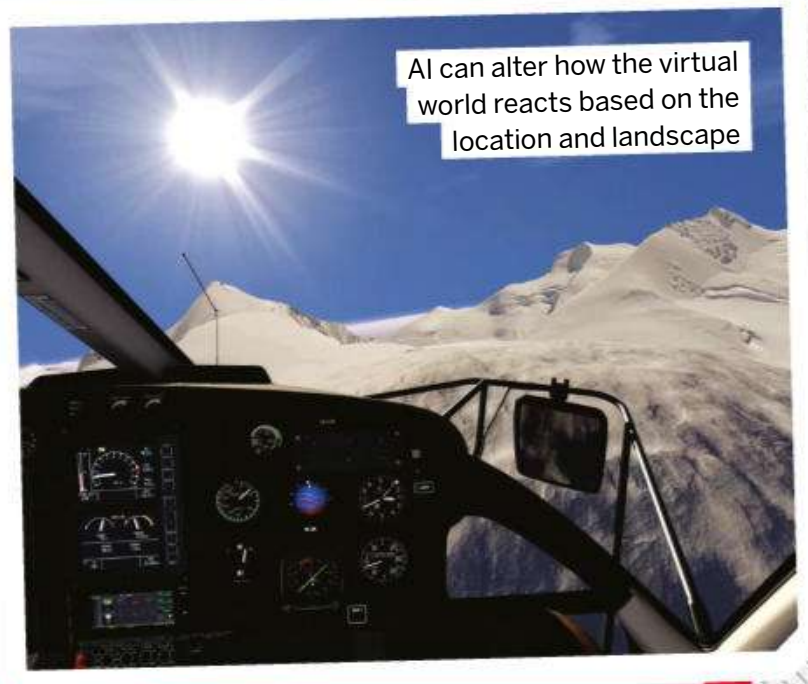
3 HAND-TRACKING CAMERA

This camera, developed by Ultraleap, tracks the movement of each finger at all times so you can interact with the virtual world using hand movements.

AN INTELLIGENT BATTLESPACE

When replacing physical training spaces with a synthetic world, artificial intelligence (AI) is essential in providing trainees with a realistic platform to make their own decisions and mistakes. Almost all of the decisions a trainee soldier will make during a mission will have an impact on a battle. The AI system is prepared with masses of training data, which includes a complex series of patterns and correlations.

AI can also produce realistic interactions with virtual surroundings, including intelligent agents. Intelligent agents are independent entities inhabiting a virtual world. For example, unlike the avatars of trainee soldiers, civilians in a virtual training battle zone aren't controlled by a real person. But with AI, soldiers can still interact with them and incorporate this aspect of a mission into their training. This is something soldiers would usually not encounter until they were on a real-world mission. Machine-learning algorithms mean that every time a military virtual training exercise is completed, the computerised characters learn from human interactions and begin to react with increasing realism.



AI can alter how the virtual world reacts based on the location and landscape

DID YOU KNOW? The Varjo headset tracks your eyes at 200 movements per second

One of the flight-simulation machines that can be plugged into Project OdySSEy

7 VIDEO PASS-THROUGH CAMERA
Captured video from dual 12-megapixel cameras passes through the headset, where real-life items are merged convincingly with VR. This prevents VR appearing like a hologram in the viewed footage.

Did you know?
The first VR headset was invented in 1968

Personnel who may be many miles apart can work together in one room in a virtual battle zone

VIRTUAL VERSUS REALITY: THE TRAINING IN ACTION

Project OdySSEy's head of training Lucy Walton describes her experience with launching VR missions

What are the main benefits of the armed forces using this VR training tool?
Sustainability is definitely one. Not doing training live saves a huge amount of emissions, and it's repeatable. When you're doing something live with an aircraft, you're going to get one shot because you're going to run out of fuel and need to go back. With VR you can restart a scenario at the push of a button. I speak to a lot of the aircrew who say this would be beneficial for them – knowing they can rehearse and do wrong now so that they learn all those key points before doing it live in the air.

Does it improve tactics?
There's almost no part of the Earth that isn't monitored anymore, with people watching 24 hours a day, seven days a week. In the simulated environment, we can deploy more realistic tactics than you would live. We have to redact them when we do it live because we don't want people to be able to see what we're up to.

How true to life are the simulated training locations?
Essentially, you can take any part of the world from a terrain perspective, and there's lots of companies we're working with at the moment that are starting to develop streaming services, so you can almost stream that terrain and the updates live. We take images from satellites and very quickly put that through an AI engine. It will recreate what that looks like from a simulation terrain. As you're starting to move towards more realistic live exercise rehearsals, you need that terrain to be updated much more frequently, because one day a building might be there and the next day it might not.

How predictable are the AI environment and civilian reactions in the simulations?
AI changes how civilians behave each time. For example, we had some simulated people that we wanted to leave a scenario, so we brought in some really low-level aircraft, which is called a show of force, and those people ran away very scared. Then we did it again, and a third time. By the third time they stopped running, as they had learned nothing bad happened afterwards, so they started to walk away, rather than running away terrified. It's quite interesting to see how their behaviour set learned that.

Historically, when we've done training in this way, everything is controlled by humans. The exercise director knows everything that's going to happen in an exercise before it starts. When you start to inject AI, it changes. In one exercise, we had a convoy of cars that were going to do a resupply mission, and a civilian crashed on the road. We're working to balance keeping the AI realistic and training people when you don't necessarily know the scenario.

© Varjo / BAE Systems

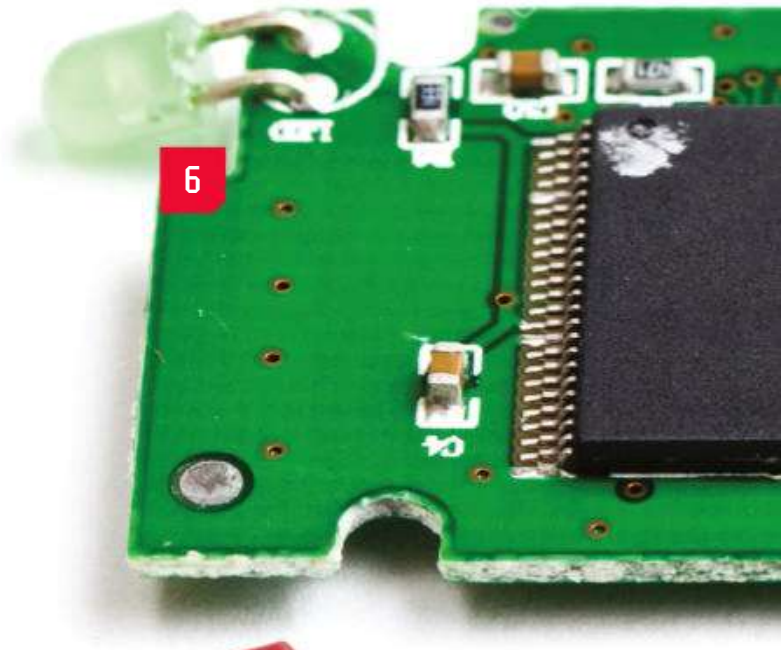
Offering more storage space, the memory stick replaced the floppy disk in the 2000s

HOW USB DRIVES WORK

The humble flash drive reinvented the way we store and transfer computer files

WORDS JACK PARSONS

6 LIGHT-EMITTING DIODE (LED)
This light shows when the USB is connected and flashes so you know when data is transferring.



Some models come with covers to better protect the USB connector

Did you know?
9.8 million memory sticks were dumped in UK landfills last year

20 years ago, this gadget was a game-changer. The fact you think nothing of how commonplace they are today just goes to show what an impact they've had. Also known as a USB stick, flash drive or pen drive, a memory stick is a portable way of storing and transferring data. Its seemingly simple design is a clever combination of two technologies: flash memory and the universal serial bus (USB). Developed in the 1980s, flash memory was an innovative alternative to traditional hard drives and floppy disks. Unlike these storage options, flash memory didn't have any moving parts. This meant it was less likely to break and could transfer data faster. The USB connector was created to make using a PC simpler. It replaced a bunch of different-shaped cables that you needed just to use your mouse, keyboard and printer with one type that could transfer both data and electrical power.

At the turn of the millennium, flash memory chips were affordable and USB ports were on almost every computer. An Israeli company called M-Systems filed the patent for a 'USB-based PC flash disk' in April 1999. That same year, American tech giant IBM filed an invention disclosure for a similar concept. But Singapore-based Trek 2000 beat them both to market, selling the ThumbDrive in early 2000.

Memory sticks were an instant hit. Over the next ten years, the technology only got better, boosting the size of memory, speed of transfer and cutting the cost of chips further. In an increasingly wireless world, physical storage can seem old-fashioned. More and more people are moving their files to the Cloud, only downloading them from the internet when they're needed. But the USB stick is stubbornly sticking around... at least for now.

MEMORY LANE

1980
Fujio Masuoka, an engineer at Japanese electronic firm Toshiba, invented flash memory. In the following years he developed both NAND and NOR types.

1995
A group of tech companies, including Microsoft, Intel and IBM, developed the USB connector to make linking to PCs simpler.

2000
Singaporean company Trek 2000 International sold the first USB flash drive: the ThumbDrive.

2001
A second generation of USB launched, able to transfer data 40 times faster at 480 megabits per second.

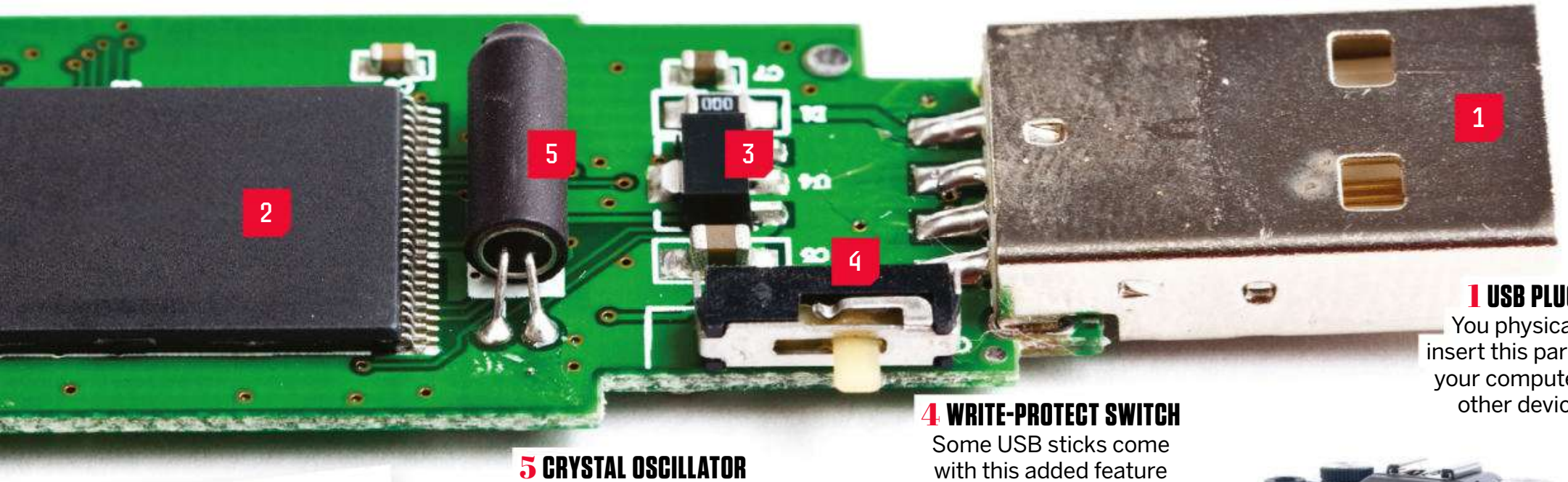
DID YOU KNOW? £5.62 billion ($7 billion) worth of memory sticks were sold worldwide in 2021

2 FLASH MEMORY CHIP
Unlike traditional computer hard drives, this memory chip has no moving pieces, so it isn't easily damaged.

3 USB MASS STORAGE CONTROLLER
This chip talks to your computer and manages the reading and writing of data to the stick's memory.

BURSTING WITH BYTES

Shedding light on the flash drive's circuit board



1 USB PLUG
You physically insert this part into your computer or other device.

4 WRITE-PROTECT SWITCH
Some USB sticks come with this added feature that prevents you from accidentally deleting data when it's turned on.

5 CRYSTAL OSCILLATOR
This quartz gemstone vibrates – or oscillates – regularly, acting like a clock for the device to know when to send signals.

DEAD DROPS: PLUG IN IF YOU DARE

Have you ever seen a memory stick sticking out a wall? There are over 1,000 so-called 'dead drops' worldwide. Inspired by the way Cold War spies hid messages for each other, German artist Aram Bartholl embedded a USB stick in a New York wall in 2010. He encouraged others to do the same, and today they span four continents, offering ten terabytes of secret storage. But connect with caution. While most users share photos and videos, there's a risk a dead drop might contain malware that could infect your device.

WHAT IS FLASH MEMORY?

USB sticks rely on a system called 'flash memory'. This uses tiny electronic switches called memory cells to store information. Each memory cell can be in one of two states, representing a zero or a one. These states are set by sending electric charges to the cells, flipping the switches. This process is how you write, or 'program', data into the memory. If you want to change the data, you can send different charges to the cells. Quick as a flash – hence the name – this erases the old information and writes new data in its place. There are two main types of flash memory: NAND and NOR. NAND is better for storing files as it has a large capacity, while NOR has fast 'random access' to data – meaning it can quickly find and use the right information. Though less common, NAND USB sticks are great for installing software updates offline.

2003
Storage capacity for USB flash drives grew. They started at 8MB and in this year reached 500MB.

2006
Nothing in My Way by British pop band Keane was the first song to be sold on a memory stick.

2008
The third generation launched, which could transmit five gigabits per second – ten times faster than USB 2.0.

2010
Infected memory sticks helped spread the world's first cyber-weapon, Stuxnet, in an attack on Iran's Natanz nuclear facility.

2015
The first flash drive with a USB Type-C connector launched, which worked even if you plugged it in upside down.

2023
Today, top-of-the-line models like the Teamgroup C231 can store two terabytes – that's over 26 million times more than the first USB sticks.

© Alamy / Getty / Teamgroup / DAM gallery & xpo gallery/Aram Bartholl

MATERIALS THAT WILL CHANGE EVERYTHING

From the surfaces of roads to the surface of our skin, the materials revolution is here

WORDS MARK MIODOWNIK

A wearable circuit, transferred onto skin

COMPUTING

PLASTIC ELECTRONICS

Electronics are moving away from being components connected by wires and becoming an intrinsic part of buildings, cars and clothing. The technology making this possible is plastic electronics. These are polymers – large molecules composed of repeating subunits – manipulated to conduct and store electricity. With these, you can print circuits and even batteries, incorporating them into products as they are made.

At the moment, tattoos are purely decorative, but electronic tattoos are on their way. These are electronic circuits with built-in sensors, applied as transfers, that can stretch with the skin. They'll enable us to interface with computers and robots by tapping our skin's surface. They will also measure our temperature, the stretch of the skin and electric signals emitted from the body. In the future, we'll be using them to monitor our health.

TRANSPORT

SELF-HEALING ROADS

Roads that heal themselves are coming, and not a moment too soon. Our roads are made of a cheap composite material comprising black asphalt and stones. But these asphalt roads are prone to damage. Under constant use, the stones in the surface of the road come loose, leading first to small cracks, then to potholes. Eventually, this causes the disintegration of the road surface. Repair is expensive in terms of the process of digging up and replacing the asphalt, but also the lengthy delays that road closures cause. It would be far better to create roads that repair the small cracks as they form.

Self-healing asphalt contains tiny steel fibres that connect up inside the material to form conducting loops. These can be heated through electrical induction, melting the asphalt and healing any cracks that have formed before they turn into potholes. This technology is primarily being developed at Delft University of Technology in the Netherlands, where it's being tested on motorways.

Did you know?

Lotus leaves are superhydrophobic, helping this plant stay clean

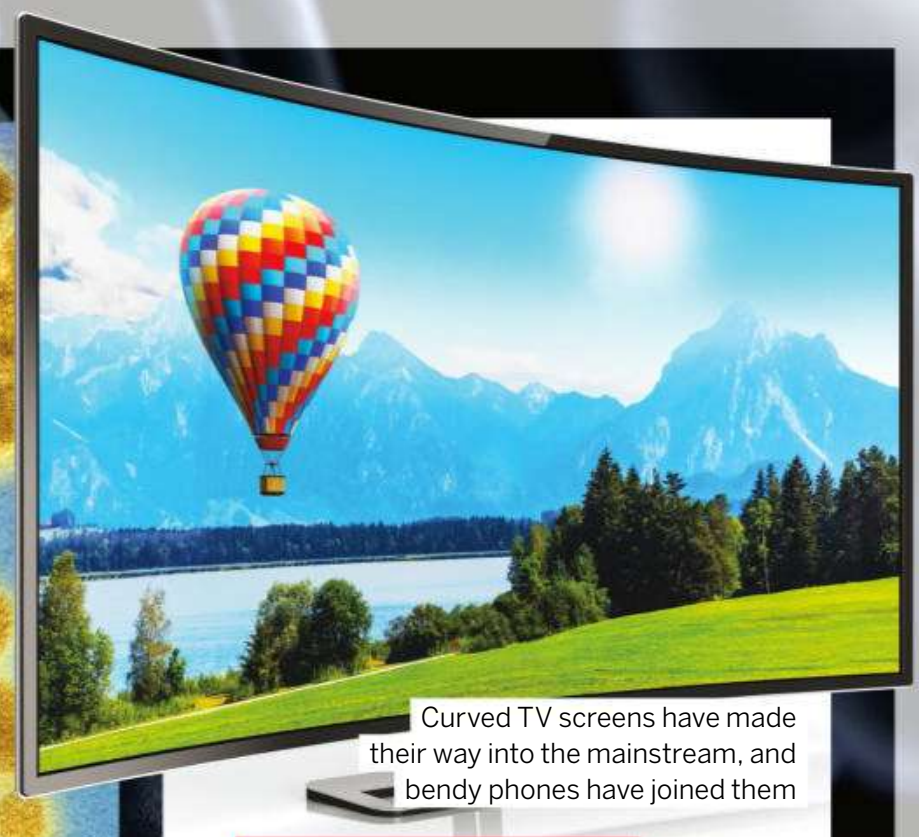
DID YOU KNOW? Asphalt is a semi-solid form of petroleum; it's almost impossible to separate all the molecules that are in it

HEALTH

GOLD NANOPARTICLES

The colour of gold nanoparticles changes with their size. This is caused by something called plasmon resonance – the oscillation of electrons in the particles. Different-sized particles have different resonant frequencies, which causes the different colours. This is useful because the size of gold nanoparticles in a liquid changes in the presence of specific proteins associated with diseases such as cancer or malaria. When the gold nanoparticles attach to the proteins, it causes them to clump together, effectively increasing their size and changing the colour of the liquid. The beauty of such a test is that it can be carried out by anyone, provides a clear result and doesn't require sophisticated or expensive equipment. It is also cheap – although it uses gold, the fact that this is in nanoparticle form means the quantities are tiny. It used to be that pregnancy tests were the only medical test administered at home – gold nanoparticles will change this fact.

Gold nanoparticles clump together when certain proteins are present and can be used in medical tests

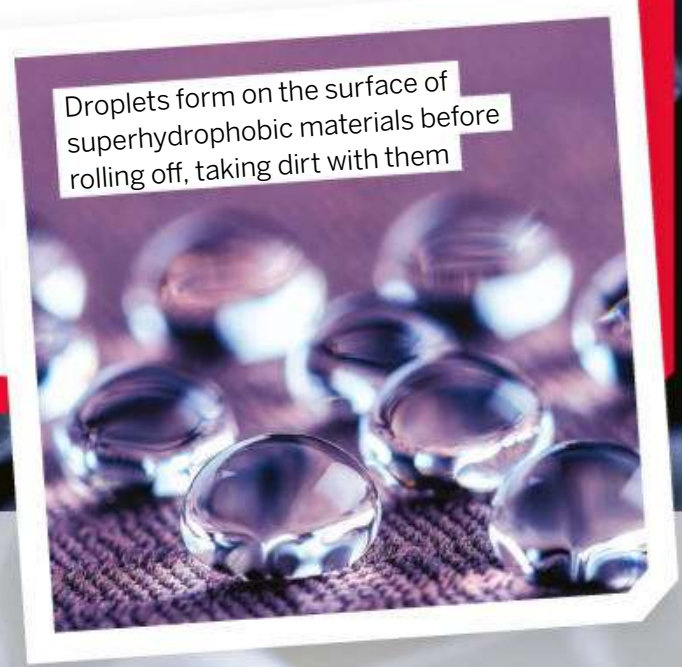


Curved TV screens have made their way into the mainstream, and bendy phones have joined them

CONSTRUCTION

SUPERHYDROPHOBIC MATERIALS

Hydrophobic materials repel water, but superhydrophobic materials repel water so effectively that droplets skitter about on their surface. Hydrophobic materials tend to be oily or waxy chemicals that distribute their electrons so differently from water molecules that the substances prefer not to mix. Superhydrophobic materials have the same chemistry, but also have incredibly rough surfaces. This means that water droplets sitting on them are forced to sit up as spherical balls of liquid. These droplets are very mobile, so they tend to skid off the surface. The advantages of this are not just increased water repulsion, but also a self-cleaning mechanism, since the droplets pick up dust from the surface and carry it off. The technology is already used in buildings, phones and on clothing to keep them dry and clean, but will become increasingly important.



Droplets form on the surface of superhydrophobic materials before rolling off, taking dirt with them

CONSUMER ELECTRONICS

FLEXIBLE OLEDS

We're used to our screens being hard, flat and rectangular. But this is changing as flexible materials called organic light-emitting diodes (OLEDs) start to become more dominant. These materials are polymers, similar to plastic polythene, but are semiconductors like silicon. As a result, they can be made to emit light. Being plastics, they can also be printed onto a variety of curved surfaces, and they are also highly elastic, and so can even be made into screens that roll up.

Flexible OLEDs have been held back for years because of a number of technical issues – the biggest of which is that the production of pixels requires several layers of material to be joined together. This sandwich must keep its electrical and optical properties when being flexed – and that's a tough task.

People have been talking about flexible displays for years, but now electronic giants such as Samsung and Sony are producing foldable and bendable phones. In the future, we're likely to see flexible OLED screens used as rollable displays and electronic paper. And there's no reason why they can't become part of clothing and wallpaper, too. Displays have already been produced that are so flexible they can be wound around a pencil.

© Getty / Alamy / Shutterstock

ADVERTISEMENT

THE WEEK Junior Science+Nature
MAKING SENSE OF THE UNIVERSE

Give the gift of wonder all year long

3 ISSUES FOR £5

Have you considered getting the children in your life a subscription to *The Week Junior Science+Nature*, a gift that will keep giving every month of 2024?

With our early bird offer, you can get your first **3 issues for just £5** plus **a free gift card** to wrap up this Christmas.

Science+Nature magazine takes children on epic voyages of discovery and brings STEM subjects to life. Readers will uncover the wonders of the universe and learn more about our precious planet.

In each issue they'll find amazing wildlife, exciting high-tech inventions, inspiring role models, surprising discoveries and brilliant activities. It's packed with big ideas, eye-catching images and fascinating facts they'll love sharing with friends and family.

PLUS Christmas gift card

Visit sciencenature.theweekjunior.co.uk/christmaspage3 to claim your offer

SPECIAL OFFER FOR READERS IN NORTH AMERICA

TRY 3 ISSUES FOR $3*

WHY WE'RE MADE OF STARDUST
HOW IT WORKS
VR BATTLEFIELD TRAINING
DISCOVER YOUR SIXTH SENSE
DO YOU PERCEIVE THE WORLD AROUND YOU IN WAYS OTHER PEOPLE CAN'T?
12 SECRET UNDERGROUND STRUCTURES
WHY THIS PLANT CHANGED LIFE ON EARTH
SEEING INVISIBLE COLOURS
GAZE DETECTION
SPIDER SENSES
SUPER SMELLER
WHAT IS SEA FOAM?
SOUNDPROOFING SCIENCE
HOW HADRIAN'S WALL WAS BUILT
WHERE DOES YOUR POO GO?
WHAT IF THERE WAS NO GRAVITY?
DOLPHIN CHAT EXPLAINED
WHAT ASTRONAUTS DO ON THE ISS
DOES BIGFOOT REALLY EXIST?
PLUS TEN MONSTER MYTHS BUSTED OR PROVEN BY SCIENCE
WHAT IS 6G NETWORK TECHNOLOGY?
DO VITAMIN PILLS WORK?
SOLAR CARS OF THE FUTURE
INSIDE A GREEN ENERGY HOME
SPECIAL
DISCOVER YOUR SIXTH SENSE

"The action-packed science and technology magazine that feeds minds"

Order hotline **+44 (0) 330 333 1113**

Online at **magazinesdirect.com/hiw/B69G**

***Terms and conditions** Offer closes 30 December 2023. Offer open to new subscribers only. After your first three issues, your subscription will continue at the price shown at the point of purchase. We will notify you in advance of any price changes. Please allow up to six weeks for delivery of your first subscription issue, or up to eight weeks overseas. Payment is non-refundable after the 14-day cancellation period unless exceptional circumstances apply. For full terms and conditions, visit **www.magazinesdirect.com/terms**. For enquiries please call +44 (0) 330 333 1113. Lines are open Monday to Friday 08.30 to 19:00 and Saturday 10:00 to 15:00 UK time or email: **help@magazinesdirect.com**. Calls to 0330 numbers will be charged at no more than a national landline call, and may be included in your phone provider's call bundle.

JUST $1 PER ISSUE!

BRAINDUMP

Amazing answers to your curious questions

Is there a limit to quantum computing?

Today's computers process data as bits, which can exist either as a zero or a one. Hard drives store these bits as microscopic patches of magnetism on magnetic plates, where the information can then be converted to electrical signals. Quantum computing, meanwhile, manipulates data at an atomic level, allowing for a whole host of interesting quantum mechanical effects. Bits in quantum computing are known as qubits and are particles such as electrons or protons. The advantages of qubits are that they are very small and can exist in more states than just two. These states could take the form of the spin of an electron or the configuration of an atom, and because there is a higher number of states per qubit than an ordinary bit, the number of possible combinations of states between different qubits increases massively. This essentially means that quantum computers would be able to solve immense calculations at unfathomable speeds compared with traditional machines. However, these particles are very difficult to manipulate, so quantum computing is currently limited in what it can do. But as for the future, it's impossible to predict how far this technology could go.

CAN GOLD BECOME A GAS?

Any element can become a gas; you just need to heat it past its boiling point. For gold that's 2,856 degrees Celsius, which is hotter than the temperature in an arc furnace, so it's difficult to boil a bar of gold. You can create small amounts of gold gas by bombarding it with a high-energy beam of electrons in a vacuum. This knocks atoms of gold free from the solid mass that fly around and coat anything in the vacuum chamber. Electron beam vapour deposition is used to create very thin gold coatings for electronics, medical and space industries.

HOW DO WE CONTROL THE VOLUME OF OUR VOICE?

The human voice is produced by air from the lungs moving over the vocal cords in the larynx. It is the force and speed of air passing over them which dictates the volume of our voices, and this air originates from the lungs. When you want to speak loudly, you take a deep breath in to fill your lungs before expelling the air rapidly and forcefully over the vocal cords.

HOW DO YOU FIX A DISLOCATED LIMB?

Joints are vital to allow movement and function to an otherwise rigid skeletal frame. The more free the movement, the less stable the joint. For example, both the hip and shoulder are ball-and-socket joints. Since the hip has a deeper socket, it is more stable, but this comes at the cost of restricted movement. The shoulder has a shallower joint and allows more freedom of movement, but is less stable.

When a joint dislocates, such as after a fall or a sports injury, contact between the surfaces of the bones forming that joint is lost. Shoulders, fingers, toes and elbows are commonly dislocated, with knees, ankles and vertebrae less frequently. The bones must then be put back in place; after some sedation, they are manipulated until they move back into the right position. Sometimes an operation is needed, but in some cases, nothing is needed at all, such as for dislocations of the collarbone.

Did you know?

The Airbus A380 is the fastest passenger plane

CAN YOU DO A LOOP THE LOOP IN A PASSENGER JET?

To perform a 360-degree loop, an aircraft needs to achieve three phases in quick succession: the entry, the climb and the exit. Each of these would cause particular problems to anything the size and weight of even a small commercial jet. Entry has to be undertaken at top speed to carry the plane through vertical ascent, making optimum fuel load a tricky calculation. At this velocity, the climb would put massive strain on the wings and tail – enough to tear them from the fuselage. Finally, the jet's weight would be too great and flight controls too weak to pull out of the loop without causing vibrations that could rip the aircraft apart. Needless to say, nobody has found a pilot brave enough – or an airline dumb enough – to try it.

What caused the train derailment at Montparnasse in 1895?

This incredible photo of a wreck at Gare Montparnasse in Paris shows a very dramatic scene of a train that crashed through the wall and partially tumbled into the street. The cause? Both mechanical failure and human error. The train was late, so the driver pulled into the station at high speed. It had two different types of braking systems: handbrakes and an air brake known as a Westinghouse brake. The conductor realised that the train was going too fast and applied the Westinghouse brake, but it didn't work. He then waited too long to use the handbrakes, which weren't sufficient due to the weight and speed of the train – Thus the locomotive crashed through a wall. Amazingly, only a few passengers and train employees were injured, though one pedestrian on the road below was killed.

© Getty

BRAINDUMP

WHY ARE MICROCHIPS MADE OF SILICON?

Most microchips are made from silicon due to its effective semiconducting properties. A semiconductor is something which conducts electricity, but only partially. Semiconductors are the foundation of most electronic devices as they allow the building of gates and switches in a circuit. Pure silicon is actually an insulator, but becomes a semiconductor through a process known as doping. Doping involves introducing small amounts of impurities, giving rise to free electrons, or 'holes' that electrons want to move into. Silicon has been so widely used in microchips as it is easy to extract from sand in large quantities. However, current research suggests that materials such as carbon graphene are able to outperform silicon, and could represent the future of consumer electronics.

If Earth was once molten, where did all the water come from?

Earth is the only planet in our Solar System with huge amounts of water that has mostly remained in the same liquid state ever since it first formed. The latest theory explains that, after the world formed – but before it had developed an atmosphere – a variety of gases were released from the interior. This 'degassing' process lasted for about 100 million years, after which time enough gases – including carbon dioxide, methane and ammonia – existed to form the atmosphere, as well as the vast oceans which cover so much of our planet today, around 70 per cent. Gravity held the gases to the surface, and the temperature lowered below water's boiling point, so the gases could condense into water. Other contributors include water-rich meteorites and comets colliding with Earth's atmosphere, and the photosynthetic processes of bacteria that existed early in the planet's life.

WHEN WILL VIDEO GAMES LOOK LIKE REAL LIFE?

In some respects, the animations used in video game cutscenes can already look uncannily realistic. However, the human eye works differently to a monitor, and the brain very differently to a computer, so the way we perceive realism and the way we recreate it are hard to compare. For starters, our eyes and retinae are curved. Though we can easily calculate the screen resolution of a video game in dots per inch, that assumes viewing it on a flat screen of a fixed size at a fixed distance. But human vision works in arcs – an object's sharpness and clarity appearing minutely different depending on how close it is. Games are also viewed on a single screen, whereas we see the world with two eyes that cover much wider peripheral vision. Even when playing a 3D game on several linked 3D monitors, it's a long way from being as convincing as the real thing.

WHAT WAS THE FIRST SPECIES MADE EXTINCT BY HUMANS?

It was likely a giant mammal species around 60,000 to 12,000 years ago. Recent studies of the wombat-like *Diprotodon* and the two-metre-tall flightless bird *Genyornis* indicate that they became extinct from Australia soon after humans arrived. These animals would either have been hunted directly or driven extinct by environmental destruction as early humans lit brush fires to flush out other prey and clear land for settlement.

WHAT'S THE DEEPEST HOLE WE'VE DUG?

The record for subsurface drilling is held by the Kola Superdeep Borehole in Russia. The project reached 12,262 metres in 1989 before 180-degree-Celsius temperatures forced it to stop. The trouble with drilling to Earth's core is not just the tough rock, crystal and molten metal you'll encounter, but the rapidly increasing pressure, friction and heat. At around 1.5 million metres, temperatures would exceed 300 degrees Celsius – more than any drill bit can cope with.

Why do bees die after they sting us?

Most bees and wasps don't. The standard stinger design is smooth for puncturing the skin of other insects and can be easily withdrawn and reused. But the honeybee has evolved a strongly barbed stinger as a defence against vertebrates. The bee doesn't just push the stinger into you – the barbs on either side of the central stylus act as ratchets that move back and forth to pull the stylus ever deeper. The elastic layers of your skin trap the barbs, so when you brush the bee off, the stinger tears free, along with the venom gland and part of the digestive tract. The bee dies from this huge rupture, but the muscles in the stinger continue to work, pumping venom into the wound. The abdominal juices also act as a pheromone signal to other bees to join the attack. This suicide strategy results in a much more painful sting and is the best way to protect the hive. Unlike workers, queen honeybees have smooth stingers for multiple attacks.

Did you know?

There are around 20,000 bee species

WHY IS REHEATING RICE BAD FOR YOU?

It's all in how you cooked and handled the rice. Rice naturally contains the spores of a bacterium called *Bacillus cereus*. If you cook rice correctly, then store it in a calibrated refrigerator within two hours, you have nothing to fear. The problem comes when cooked rice is kept at an unsafe temperature for a long period of time, as this allows the spores to breed. No amount of reheating after that can kill them, and eating the rice can cause diarrhoea and vomiting. Any food cooked and stored improperly can make you sick, but many people don't know rice is a potential culprit.

© Getty

Can fusion reactors break down anything into atoms?

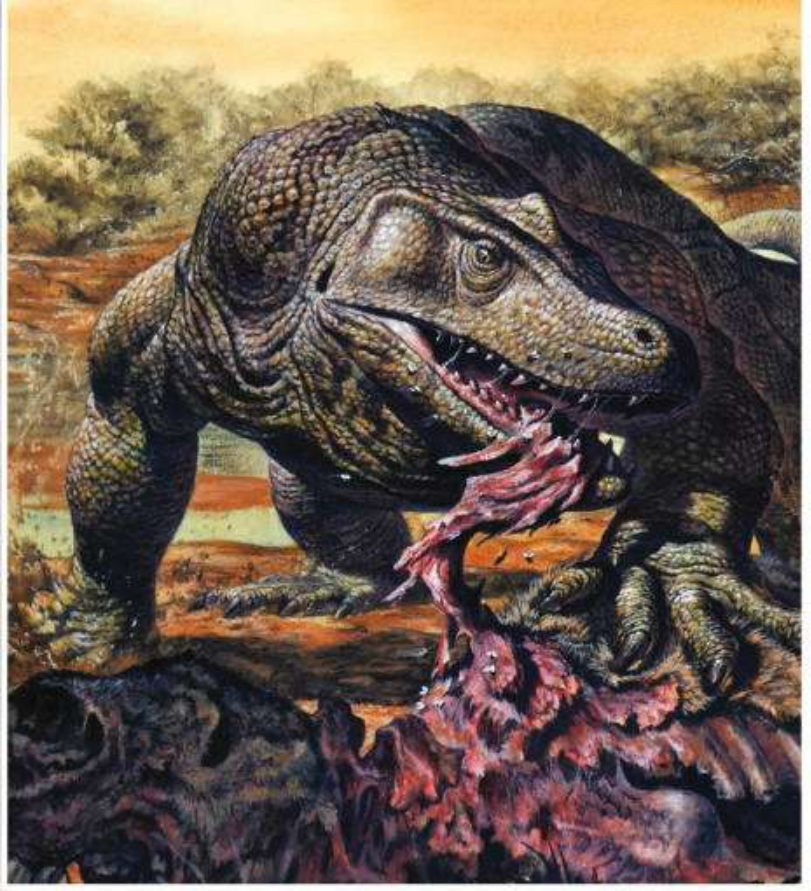
Nuclear fusion powers the Sun, and it happens when hydrogen nuclei fuse together to make helium nuclei. Extremely high pressures and temperatures of around 10 million degrees Celsius inside the Sun allow fusion to occur. On Earth the temperature inside a fusion reactor has to be much higher – around 100 million degrees Celsius – to compensate for our inability to create similar pressures to those found in our Solar System's star. In such extreme conditions, hydrogen and helium exist as plasma, where all the electrons are stripped off atoms and can move freely. Anything else present inside a fusion reactor would therefore break down into its elemental parts as a result of this subatomic deconstruction.

Did you know?

Fusion doesn't emit pollutants or greenhouse gases

WHAT IS DÉJÀ VU?

Déjà vu is a phenomenon in which you feel as if you're seeing or experiencing something that has already happened. It's French for 'already seen', and as many as 70 per cent of people have had déjà vu experiences. But what causes it? There are several different theories. Some neurologists suggest the brain mistakenly processes a short-term memory – the memory you're in the process of making – as a long-term memory, making something that's new seem familiar. Another possibility is if you've learned or seen something similar, and although you've forgotten it, some aspect was stored in your consciousness, so when you have the new experience, your brain tries to match up the two. People suffering from temporal lobe epilepsy may experience déjà vu due to short-circuiting, while a number of drugs can also evoke the feeling.



WHAT'S THE BIGGEST LIZARD TO EVER LIVE?

If you were tempted to think 'some kind of dinosaur', think again – dinosaurs were similar to reptiles, but weren't lizards. The answer is *Varanus priscus*, or megalania, a terrestrial lizard native to Australia that became extinct over 40,000 years ago. Although most experts agree megalania was the biggest ever, opinion is divided on just how big it was, with estimates varying between 4.5 and 7.0 metres long. This is because no complete skeletons have been found, although fossil fragments do suggest megalania was heavily built with a mouthful of sharp, serrated teeth. The world's largest living lizard is a distant relative of megalania, the Komodo dragon, which is a kind of monitor lizard.

WHAT CAUSED THE TUNGUSKA IMPACT BACK IN 1908?

The Tunguska explosion was caused by an object several tens of metres across that detonated in an airburst 3.1 to 6.2 miles above Tunguska, Siberia, in 1908. Scientific opinion is divided as to whether the object was a meteoroid or a comet fragment. The former would have been a rocky mixture of iron ore and silicon oxides, while the latter would have been mainly ice. The explosion was 1,000 times more powerful than the Hiroshima bomb, so virtually all of the object was vaporised in the atmosphere.

Where does the fat go when we lose weight?

Fat is essential to our bodies. It stores energy, insulates us and protects us from impacts. The majority of fat is stored as subcutaneous adipose, which is the layer beneath your skin. Some is also stored in your liver and muscles. Men and women have different fat distributions, with women storing most around the breasts and hips, and men around the abdomen.

Fatty acids are the basic building blocks of lipids – the small fat molecules that are transported through the blood and have many functions. Most people have a predetermined number of fat cells, which doesn't change much. As fatty acids are absorbed into the body, they are transported in the bloodstream as chylomicrons. The liver is the master controller of the synthesis, storage and breakdown of fatty acids.

When glucose levels are low and more energy is needed, the stored fatty acids in fat cells are broken down into glycerol and fatty acids, which are free to circulate and then be absorbed by cells in need; this process is called lipolysis. The fat cells then shrink. These adipose cells don't really 'go' anywhere – they merely expand or shrink depending on the nutritional status and energy demands of the body at a given moment.

WHAT DOES IT MEAN WHEN WE ARE 'WINDED'?

A sharp blow to the abdomen can cause a spasm of the diaphragm, a dome-shaped muscle that separates the abdominal cavity from the thorax. It's the key muscle in the respiration system. When it flattens, the pressure in the lungs reduces and air flows in. When in spasm, it makes it hard to breathe for a few moments – the sensation of feeling winded. This will relieve itself rapidly if the person keeps calm and lets the spasm run its course.

IS THERE ANYTHING HARDER THAN DIAMOND?

In physics, hardness is a measure of how resistant solid matter is to various kinds of permanent change when a force is applied. Hardness can be measured on the Mohs scale, where diamond is the hardest natural material. Diamond is made from carbon atoms joined by strong covalent bonds. There are harder synthesised materials: aggregated diamond nanorods are made by subjecting carbon-60 to immense pressures.

© Alamy / Getty

THE LIBRARY

The latest book releases for curious minds

BOOKS AND THE PEOPLE WHO MAKE THEM

FROM AUTHOR TO PRINTING PRESS

AUTHOR **STÉPHANIE VERNET**
ILLUSTRATOR **CAMILLE DE CUSSAC**
PUBLISHER **PRESTEL**
PRICE **£14.99 / $19.99**
RELEASE **OUT NOW**

How many of you have read a book and thought about how the author wrote it? Probably quite a few of you, especially if you're thinking about an unusual story you particularly enjoyed, and definitely more than the number of people who have thought about how publishing a book works. *Books and the People Who Make Them* details this entire process, from the inspiration that prompts a writer to put their proverbial pen to paper to the moment the bound and printed tome is picked off the bookshelf. This is no technical manual for a publisher to refer to. Author Stéphanie Vernet and illustrator Camille de Cussac have put together an eye-catching work that is easy to understand, broken down into the people involved at every step along the way: author, editor, illustrator and graphic designer to sales representatives, printers, booksellers, critics, librarians and finally into the hands of the readers. It's detailed despite this relative simplification and includes discussion around the use of fonts, royalties and how authors get paid, answering questions like what a sales representative does, how the publisher chooses a release date and more.

Vernet also draws on real-world examples of people in book publishing and the relationships between the different roles – such as that of writer Raymond Carver and his editor Gordon Lish, who drastically cut Carver's text, resulting in huge success for his work. And it all has some relevance to magazine publishing too, in case this has made you wonder how each issue of **How It Works** is created. In fact, having read this book cover to cover, we've learned more than just a thing or two about the book publishing process ourselves. It's a fascinating read, and you don't have to be in the publishing industry to enjoy *Books and the People Who Make Them*, either. Pitched at ages eight and over, there's still plenty to enjoy for any adult reading this with their children.

"Vernet and Cussac have put together an eye-catching work that is easy to understand"

LITTLE PEOPLE, BIG DREAMS: SALLY RIDE

MEET THE WOMAN WHO BECAME NASA'S FIRST FEMALE ASTRONAUT IN SPACE

AUTHOR **MARIA ISABEL SÁNCHEZ VEGARA**
ILLUSTRATOR **ALONA MILLGRAM**
PUBLISHER **QUARTO**
PRICE **£9.99 / $15.99**
RELEASE **4 JANUARY**

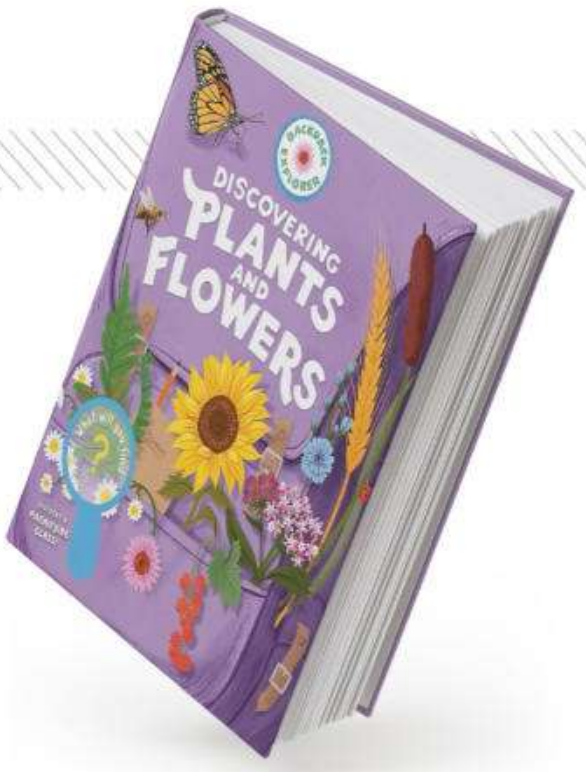
In 1983, Sally Ride boarded the Space Shuttle Challenger mission STS-7. As it broke through Earth's atmosphere, she became the first female astronaut from the US to reach space. In this edition of the wildly successful *Little People, Big Dreams* series, the next generation of astronauts will discover Ride's journey to the stars and how she helped advance our understanding of space. Once again, the charming illustrations in this series bring a playful vibrancy to the timeline of Ride's life, from her early years in California and her first NASA mission to her time as a professor and author. Ride's story is one of triumph over adversity, dedication and a passion for sharing knowledge, which this inspirational book tells so brilliantly to its young readers.

BACKPACK EXPLORER: DISCOVERING PLANTS AND FLOWERS

WHAT WILL YOU FIND OUT IN THE WILD?

AUTHOR **EDITORS OF STOREY PUBLISHING**
PUBLISHER **STOREY PUBLISHING**
PRICE **£9.99 / $12.99**
RELEASE **11 APRIL**

In this edition of the *Backpack Explorer* book series, junior naturalists will discover not only the science behind how plants grow, breathe and eat, but learn to identify the wealth of wildlife around them. From prehistoric ferns to springtime blooms, this explorer's guide takes adventurers on a tour through the woods as well as your back garden, through its flowers, grasses, water plants



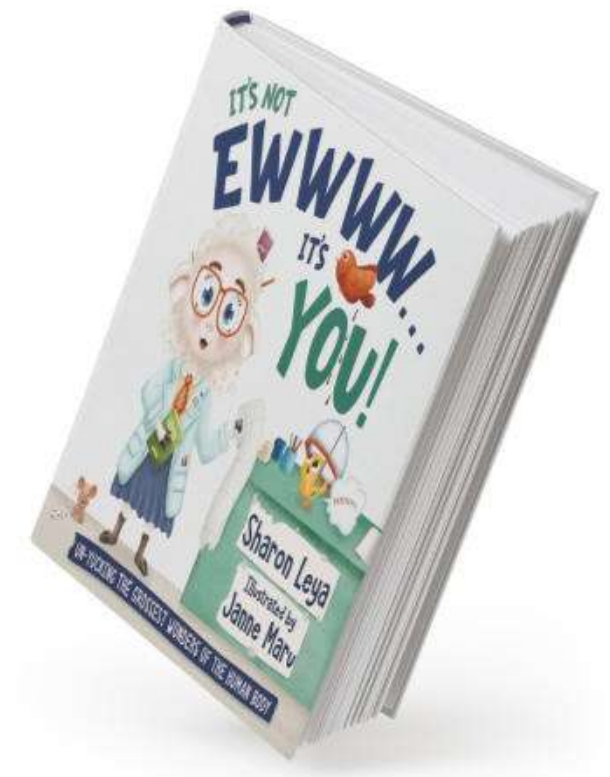
and more. The interactive elements of the book, such as the Scouts-style patch stickers for achievements in plant identification, are a brilliant touch that will certainly get children excited about being outdoors and discovering new things. Along with the book's botanical activities, there are several artistic adventures to explore, such as painting with berries and weaving branch decorations. If you're planning on taking a walk through nature with your little ones, then don't forget to have *Backpack Explorer: Discovering Plants and Flowers* on hand.

IT'S NOT EWWWW... IT'S YOU

UN-YUCKING THE GROSSEST WONDERS OF THE HUMAN BODY

AUTHOR **SHARON LEYA**
ILLUSTRATOR **JANNE MARU**
PUBLISHER **BOOKSGOSOCIAL**
PRICE **£9.50 / $11.95**
RELEASE **OUT NOW**

Our bodies do some amazing things, but some of these systems and processes might gross you out. In *It's Not Ewwww... It's You*, some of your body's most disgusting natural substances are explored, each with hilarious illustrations and compact explanations. This quirky book features an animal teacher, Professor Ewe, who brings the reader on a human biology tour. The simple read is ideal for readers between the ages of four and eight as a comedic introduction to the systems in their bodies. The descriptions are perfectly tailored towards young readers and are sure to have children giggling between pages. Readers should take the time to explore the humorous details hidden in each of the diverse illustrated scenes. Topics include nose mucus, flatulence, ear wax



and sweating – features of the body that the reader will be familiar with, and at the end of *It's Not Ewwww...It's You*, each of the gasses, liquids and solids covered in the book are explained in more detail. After learning about the cooling and protective properties of our natural secretions, children will begin to appreciate all the sounds and substances their bodies make.

THE WONDERFUL WORLD OF WATER

FROM DAMS TO DRY DESERTS

AUTHOR **SARAH GARRÉ AND MARIJKE HUYSMANS**
ILLUSTRATOR **WENDY PANDERS**
PUBLISHER **PRESTEL**
PRICE **£18.99 / $24.99**
RELEASE **OUT NOW**

71 per cent of Earth's surface and 60 per cent of your body is water, but how much do you know about water and its significance? In *The Wonderful World of Water*, you'll take a tour of the planet, exploring the basic chemistry of water, its importance for life's existence, food growth, biological health and more. This book is written for readers aged between 8 and 12 but contains masses of impressive facts that parents may have never heard. Water holds the power to become a destructive force, which you will learn all about in a chapter about waves and tsunamis. From there, topics become more complex, with the final chapters including vital information about the changing state of water due to climate change and top tips for saving water. Much of the book's most compelling writing is framed in simple science questions. If you have a science question related to water, you're likely to get it answered here.

BRAIN GYM

Give your brain a puzzle workout

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

	5	9	4	2		7		6
4	3			7	9	5		
	8			5			9	3
6	7		9	8		2	3	4
9		8						7
3		1	7	6		8		
2	1			9			6	
8					4			
5		7			8	1		

MEDIUM

		9				1		5
	2			5	8			6
5	7		6		2			
	1				3		9	8
		5			9	4		
			5		6	3	7	
			8	6				
			7	3		8		9
		8		9	5		1	4

HARD

	9				6	8		4
5			8					
7				3			1	
		6	2		4			
			1			7	5	
		2				3		
		4				5	6	3
	1			5	2			
9								7

Word search

Find the following words

DUNG
SIXTH
GRASS
WALL
CANOE
BRAIN
USB
HADRIAN
SENSES
COW
SOUND
WAR

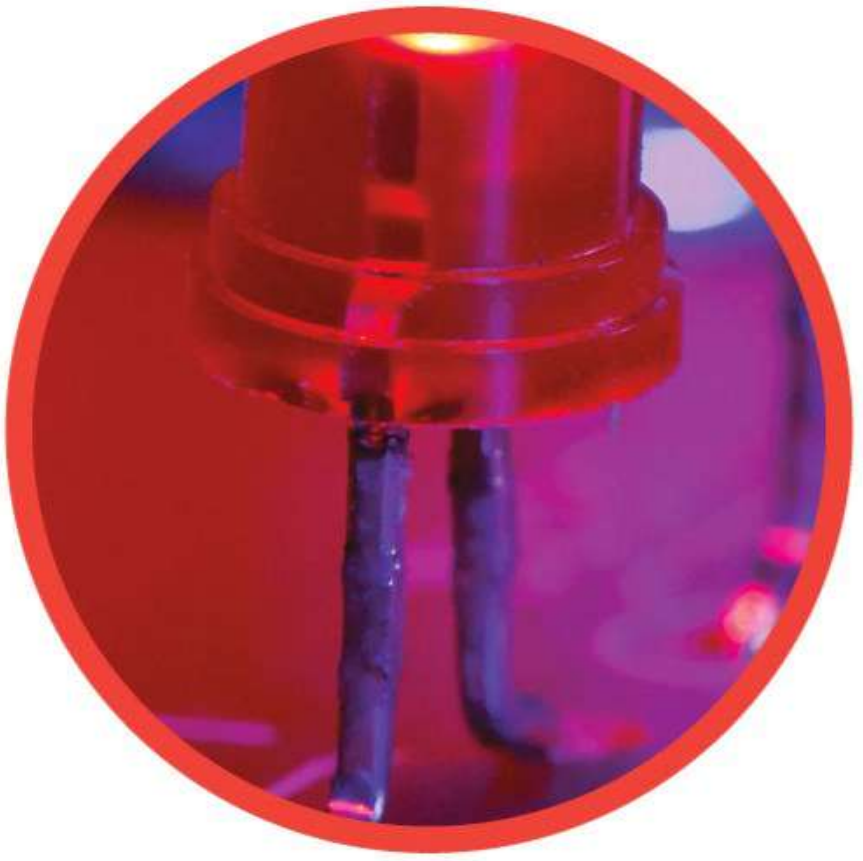
C	O	D	D	N	U	O	Z	L	T	Y	C	A	N	B
E	G	R	U	S	S	W	A	L	R	U	A	W	D	N
D	U	M	G	N	I	H	E	D	R	I	N	A	L	W
A	R	U	S	D	G	B	R	I	U	N	O	B	S	Y
S	I	Y	N	O	T	E	S	E	N	S	E	S	X	L
H	A	D	R	L	H	R	O	N	C	O	Y	M	G	N
S	S	A	R	J	F	O	W	V	S	U	N	D	R	T
Q	E	S	I	X	T	H	I	P	U	N	B	W	A	R
D	U	N	F	C	K	L	Y	N	K	L	I	U	S	D
N	I	O	E	H	A	D	R	I	A	N	Z	X	S	H
U	T	W	O	D	L	J	F	K	Z	O	L	E	N	Y
O	W	B	U	S	L	Q	S	I	X	E	C	I	N	P
S	U	S	Y	B	A	K	R	L	C	O	W	M	O	U
C	A	U	N	O	E	W	A	P	H	A	D	I	R	A
W	A	L	L	O	B	N	I	A	R	B	C	A	N	O

What is it?

Hint:

Electric light, not a bulb

A



Spot the difference

See if you can find all six changes between the images below

QUICKFIRE QUESTIONS

Q1 Which of these particles has zero mass?

- Electron
- Photon
- Neutron
- Proton

Q2 What is a whale's communication organ called?

- Apple
- Banana
- Peach
- Melon

Q3 Which of these electromagnetic waves isn't harmful to humans?

- Radio
- Ultraviolet
- X-ray
- Gamma

Q4 About how much of a car is recyclable?

- 40 per cent
- 60 per cent
- 80 per cent
- 100 per cent

Q5 What coats the James Webb Telescope's primary mirror?

- Silver
- Gold
- Steel
- Aluminium

Q6 Which of these metals has the lowest melting point?

- Gold
- Tungsten
- Lead
- Mercury

Answers

Find the solutions to last issue's puzzle pages

Q1 RUM
Q2 HUMMINGBIRD
Q3 CAPACITOR
Q4 BLACK
Q5 A YEAR
Q6 A BEAR

What is it?

PINE CONE

Spot the difference

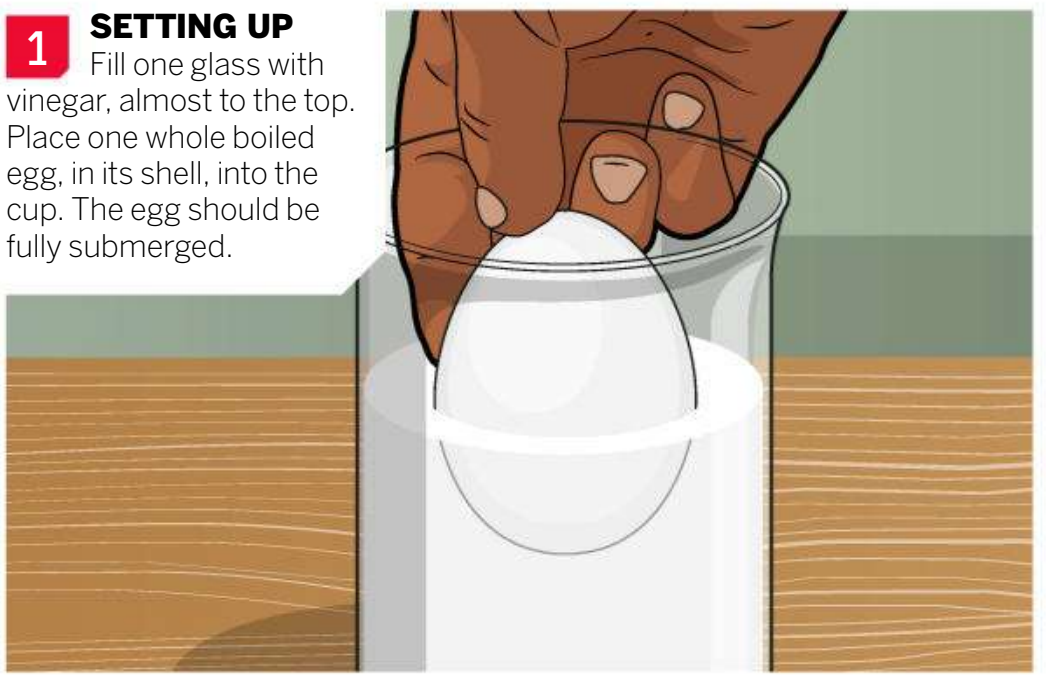
© Alamy / Getty

HOW TO...

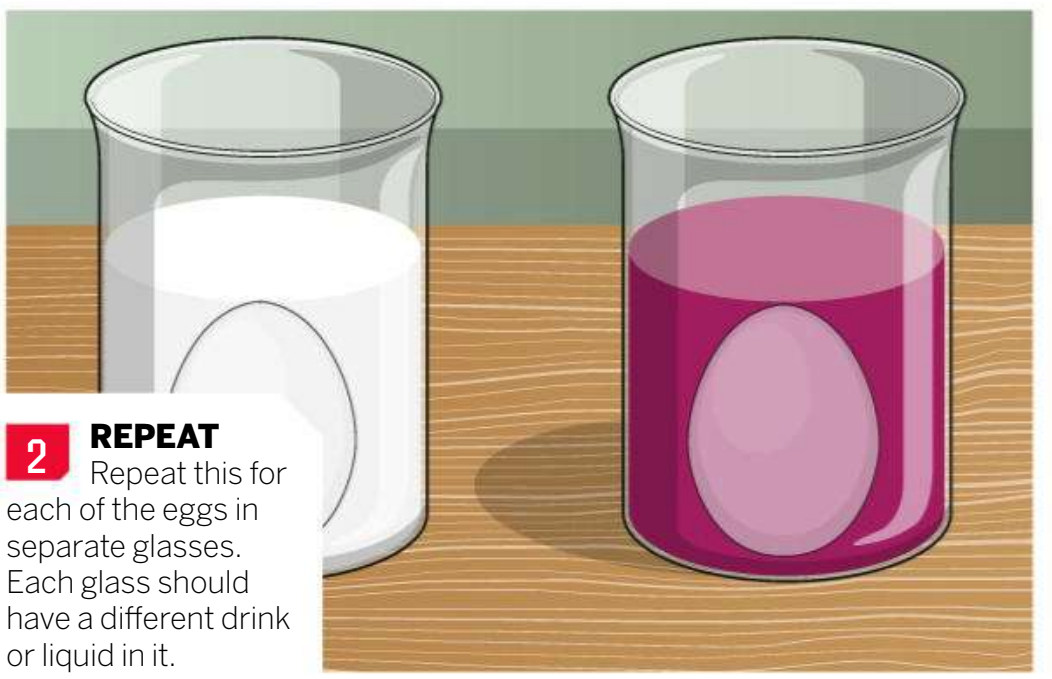
Practical projects to try at home

REPLICATE TOOTH DECAY USING EGGS

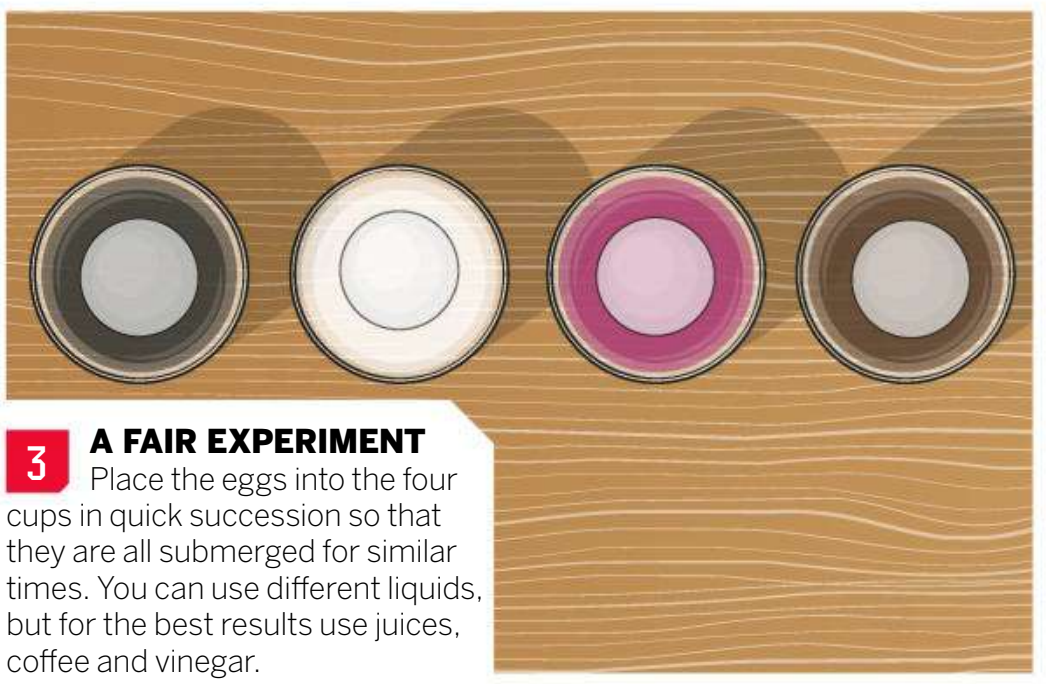
Explore the impact of different chemicals on the colour and strength of your teeth



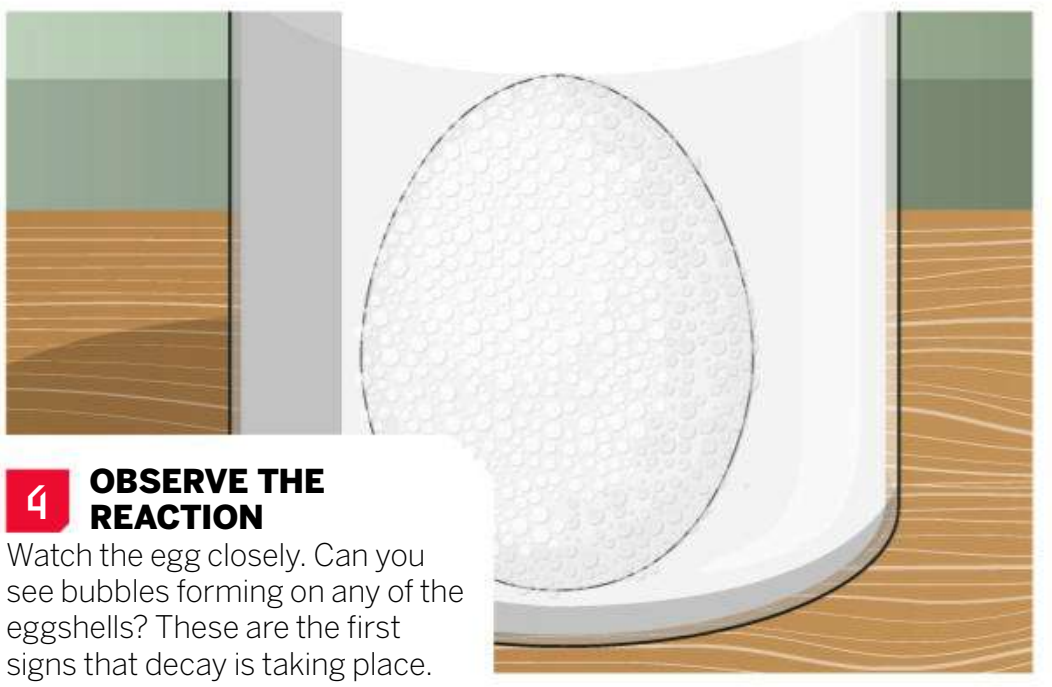
1 SETTING UP
Fill one glass with vinegar, almost to the top. Place one whole boiled egg, in its shell, into the cup. The egg should be fully submerged.



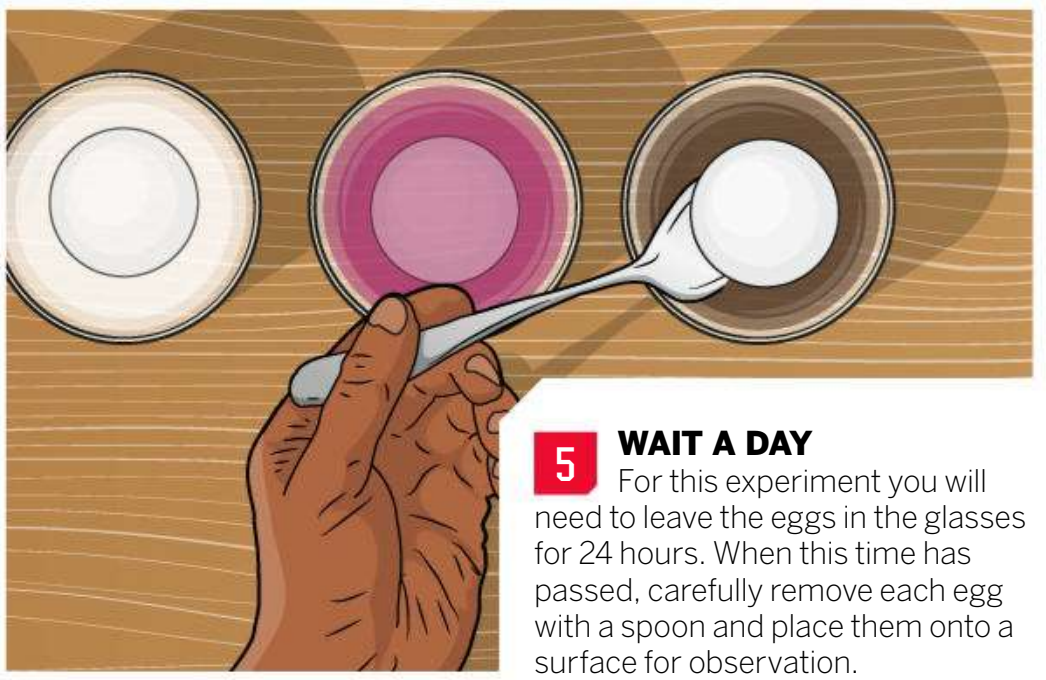
2 REPEAT
Repeat this for each of the eggs in separate glasses. Each glass should have a different drink or liquid in it.



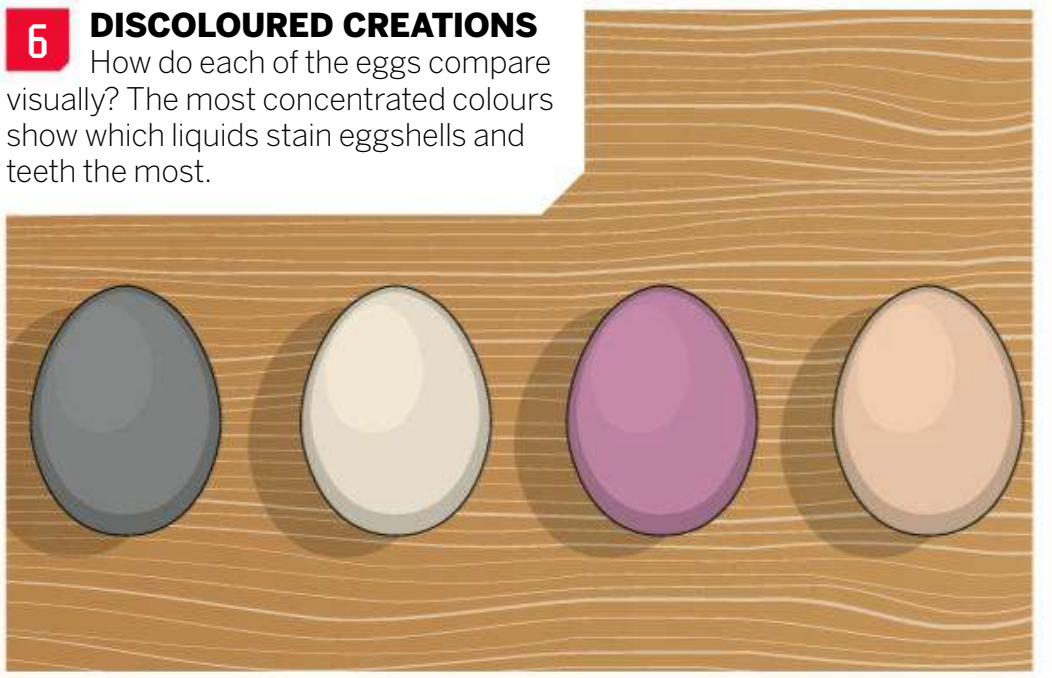
3 A FAIR EXPERIMENT
Place the eggs into the four cups in quick succession so that they are all submerged for similar times. You can use different liquids, but for the best results use juices, coffee and vinegar.



4 OBSERVE THE REACTION
Watch the egg closely. Can you see bubbles forming on any of the eggshells? These are the first signs that decay is taking place.



5 WAIT A DAY
For this experiment you will need to leave the eggs in the glasses for 24 hours. When this time has passed, carefully remove each egg with a spoon and place them onto a surface for observation.



6 DISCOLOURED CREATIONS
How do each of the eggs compare visually? The most concentrated colours show which liquids stain eggshells and teeth the most.

NEXT ISSUE
MAKE A LEMON VOLCANO

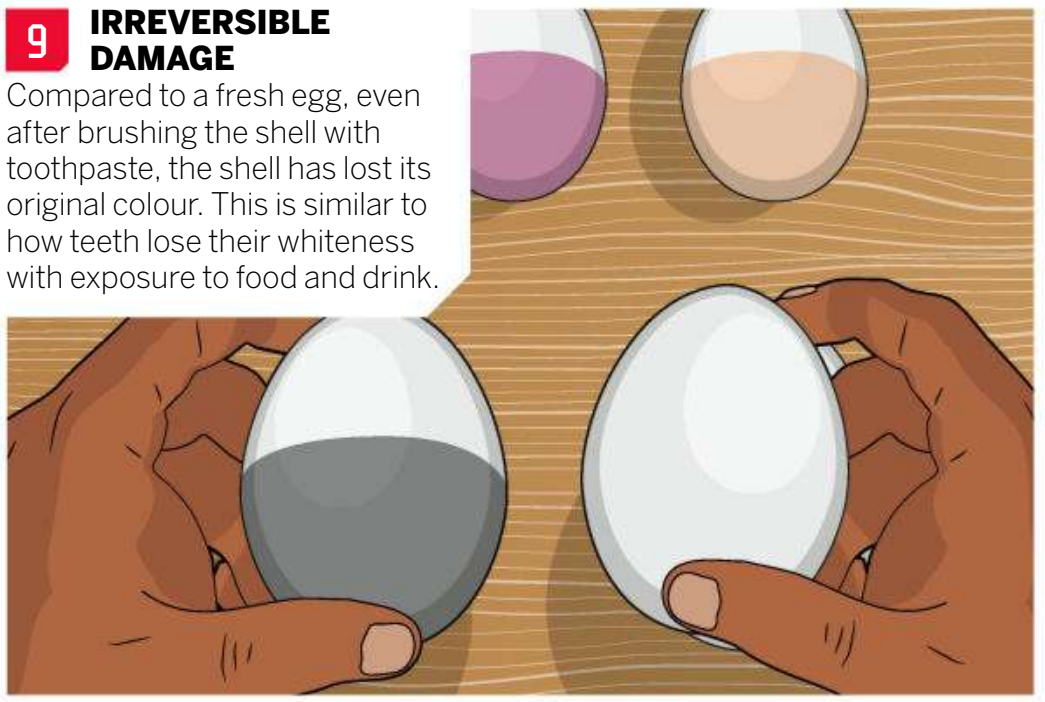
KIT LIST

- Four glasses
- Four boiled eggs
- Spoon
- Blackcurrant juice or similar
- Cranberry juice or similar
- Vinegar
- Coffee
- Toothpaste
- Toothbrush

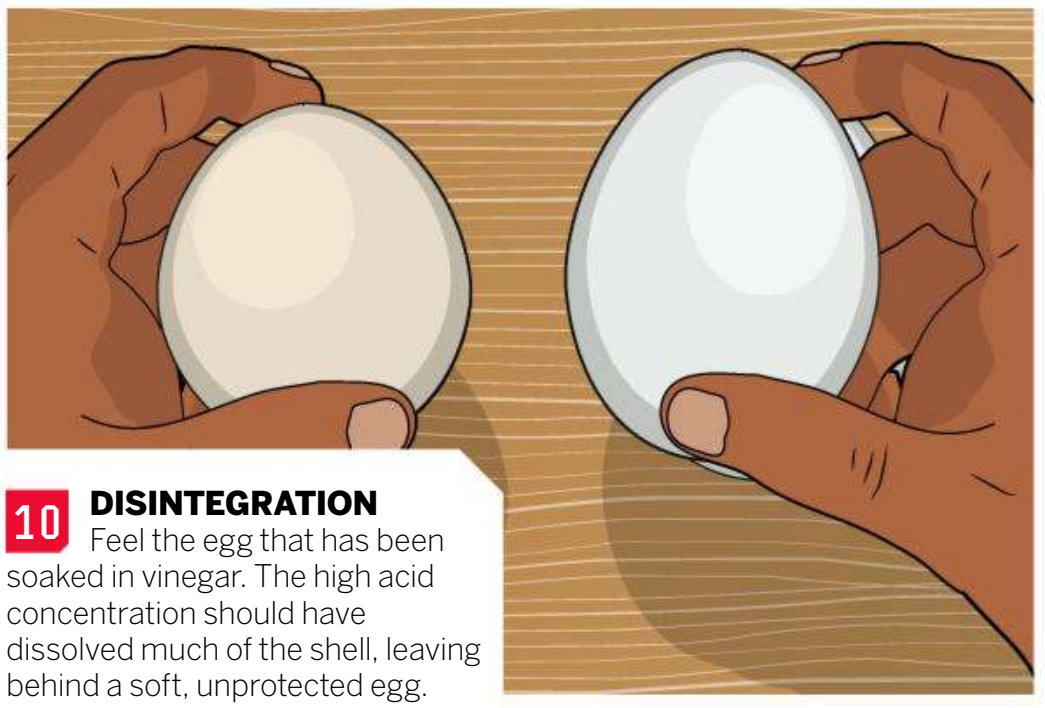
DON'T DO IT ALONE!

If you're under 16, make sure you have an adult with you

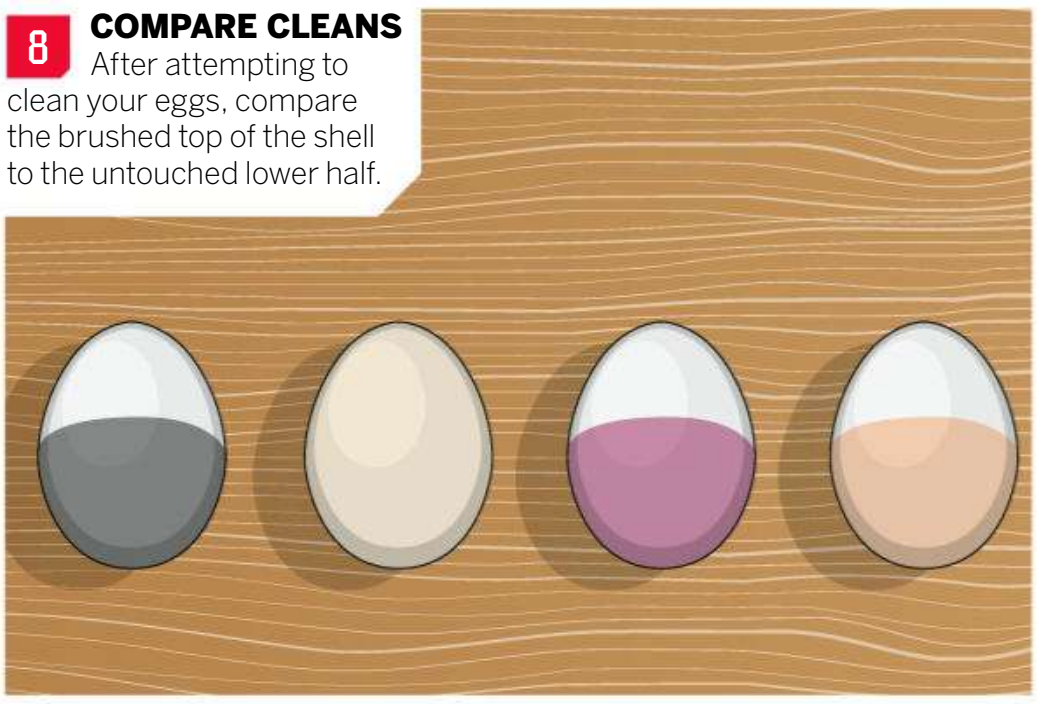
7 BRUSH YOUR 'TEETH'
Just as you would brush your teeth at the end of a day, try to clean the top of the egg with toothpaste and a brush. Make a note of whether the discolouration is washed away or not and how the shell feels.



9 IRREVERSIBLE DAMAGE
Compared to a fresh egg, even after brushing the shell with toothpaste, the shell has lost its original colour. This is similar to how teeth lose their whiteness with exposure to food and drink.



10 DISINTEGRATION
Feel the egg that has been soaked in vinegar. The high acid concentration should have dissolved much of the shell, leaving behind a soft, unprotected egg.



8 COMPARE CLEANS
After attempting to clean your eggs, compare the brushed top of the shell to the untouched lower half.

SUMMARY

Your teeth are exposed to a range of food and drink throughout the day. Any highly acidic foods, like the vinegar used in this experiment, can wear away the enamel on your teeth, just as the hard egg had a squishy texture without its shell. Tooth enamel – the hard, protective outer layer of your teeth – is made up of calcium phosphate, or the minerals calcium and phosphorus, while eggshells are made of calcium carbonate and small amounts of other minerals such as phosphorus. Their similar chemical compositions make eggshells ideal for demonstrating how your tooth enamel reacts to liquids. Once this part of a tooth is damaged and worn away, you can't grow more enamel. When sugary foods and carbohydrates are being broken down in the mouth, acid is produced, which is why it's important to brush your teeth twice a day to prevent food and acid buildup and the resulting staining and decay. Coffee contains a dye called tannin that seeps into the pores of the eggshell, or your teeth, and causes staining.

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

DISCLAIMER
Neither Future Publishing nor its employees can accept any liability for any adverse effects experienced during the course of carrying out these projects or at any time after. Always take care when handling potentially hazardous equipment or when working with electronics, and follow the manufacturer's instructions.

© Illustrations by Ed Crooks

INBOX
Speak your mind

A Sydney funnel-web spider

LETTER of the MONTH

AUSSIE ANIMALS

Dear **HIW**,
I'm going to Australia soon, and someone told me that the smallest spiders are the deadliest. Is there any truth in this? Also, I know some larger animals are native to the country, but are there any insects that are just found in Australia?
Jennifer Hart

You can't really tell how deadly a spider is from its size, and you shouldn't assume that small spiders do no damage. Some of the deadliest spiders in the world are rather small, so before going to countries with dangerous animals it's worth doing some research. In Australia, the deadliest is the Sydney funnel-web spider, with a 3.5-centimetre body length. The funnel-web spider's bite can be life threatening, but only 10 to 15 per cent of these bites are actually venomous. Although Australia is home to some dangerous species and is a concern for many people travelling there, it's worth remembering that they aren't as prevalent as you might imagine. There are more than 2,000 spider species in the country, and only a few are dangerous. If you do come across them, stay out of their way. They are unlikely to attack you unless you disturb them.

Being a large and isolated island, there are many animal and insect species that live solely in Australia. One example of an Australian insect is the Goliath stick insect. These live in the forests of Eastern Australia and grow to an impressive length of 25 centimetres. You will do well to spot one of these, though, as their green, leafy appearance makes them masters of camouflage.

WIN!
AN AMAZING PRIZE FOR LETTER OF THE MONTH

BOOKS AND THE PEOPLE WHO MAKE THEM
How a book makes its journey from the writer's notebook to the reader's hands

CRUISE SHIP QUESTION

Dear **HIW**,
We've just completed a holiday on board an American cruise ship which visited ten ports in ten days in the Mediterranean. I wondered if you knew if US cruise ships had the equivalent of sky marshals – sea marshals? – or what sort of contingencies they had for defence against terrorist attacks.
Allan Bannerman

Sky marshals are undercover law enforcement officers that are specifically trained to react to plane security threats. These marshals monitor suspicious activity on planes and help keep passengers safe. Cruise ships generally don't have a system that exactly resembles this, but they do have onboard security personnel and surveillance systems and perform preboarding scanning checks. For ships in general, sea marshals do exist, and their role is to board and search ships. They are trained to conduct thorough surveillance and maintain control of these vessels.

Security measures vary among cruise ships

OPPOSITES ATTRACT

Dear **HIW**,
Why have creatures, birds in particular, evolved with such different appearances between the male and female of the species, when often there is very little difference?
Stephen

The most common purpose is to attract a mate. Animals that experience high competition for a mate often evolve so that males are more eye-catching to females. The role differences between males and females also plays a part. A female eclectus parrot, for example, needs to remain by the nest to incubate her eggs. This is why she has a duller coat, to blend in with the tree and nest. Other species have less competition. Monogamous animals form lifelong bonds and are less likely to need an elaborate coat. Many species have evolved to maintain one common colour so that both sexes are camouflaged from predators.

The male cardinal is much brighter than the female

NEXT ISSUE ISSUE 186 ON SALE 18 JAN 2024

Available in print from all good newsagents and **magazinesdirect.com**, or as a digital edition for iOS and Android. To enjoy savings on the RRP and to make sure you never miss an issue, check out our subscription offers on pages 24 (UK) and 83 (US).

WINK OR BLINK

Dear **HIW**,
Why does a wink in each eye not feel like a blink and is there any alternative which would work like a blink?
Toby

Winking and blinking involve different mechanisms, and the circumstances under which you perform each makes them feel different. A wink is deliberate and can be used as a social cue. Your body doesn't naturally wink, so when you choose to wink you have to consciously control the muscles in your face to keep one eye open. This includes contracting muscles in your cheek on one side, giving a different sensation. Blinking is an involuntary reflex to keep eyes moist, and you rarely notice you're doing it. The brain suppresses visual input activity so you don't notice small periods of darkness. As a reflex, it's hard to replicate.

AIRPORT ORIGINS

Dear **HIW**,
When was the first airport opened? Before this, was there a time that you could launch aircraft from anywhere?
Taylor Rees

College Park Airport in Maryland is thought to be the first airport in the world, and is the oldest airport still open today. It was opened in 1909, and one of the Wright brothers who invented the first motor-operated plane, Wilbur, was first to land at the field to train military officers. Before airports, early aircraft took off from large fields and open spaces.

WE ASKED YOU

This month on social media, we asked you:

Do you have any favourite smells?

@????FATEMEH????
Rain

@MEGAN.WORTHINGTON_
Sharpie pens

CARL MORTON
LOVE THE SMELL OF PETROL BUT DON'T KNOW WHY

JENKIN D
Coffee in the morning

@MAIA_H3
FRESH BASIL

JASMINE F
Summer smells, like lit barbecues

© Getty / Prestel

HOW IT WORKS

Future PLC Quay House, The Ambury, Bath, BA1 1UA

Editorial
Editor **Ben Biggs**
Senior Art Editor **Duncan Crook**
Production Editor **Nikole Robinson**
Senior Staff Writer **Scott Dutfield**
Staff Writer **Ailsa Harvey**
Group Editor-in-Chief **Tim Williamson**

Contributors
Andrew May, Jack Parsons, Emily Cooke, Tom Metcalfe, Sharmila Kuthunur, Carys Matthews, Ben Turner, Andrew Jones, Keumars Afifi-Sabet, Connor Feehly, Hannah Osborne, Richard Pallardy

Cover images
Getty, Alamy, BAE Systems

Photography
Alamy, Getty Images, NASA, Science Photo Library, Wikimedia
All copyrights and trademarks are recognised and respected

Advertising
Media packs are available on request
Account Manager **Jagdeep Maan**
jagdeep.maan@futurenet.com
0330 390 6532
Advertising Sales Director **Lara Jaggon**
lara.jaggon@futurenet.com
07515 961911

International Licensing
How It Works is available for licensing and syndication. To find out more, contact us at **licensing@futurenet.com** or view our available content at **www.futurecontenthub.com**.
Head of Print Licensing Rachel Shaw

Subscriptions
Enquiries **help@magazinesdirect.com**
UK orderline & enquiries **0330 333 1113**
Overseas order line & enquiries **+44 (0)330 333 1113**
Online orders & enquiries **www.magazinesdirect.com**
Consumer Revenues Director **Sharon Todd**

Disruption remains within UK and international delivery networks. Please allow up to seven days before contacting us about a late delivery at **help@magazinesdirect.com**

Circulation
Head of Newstrade **Ben Oakden**

Production
Head of Production **Mark Constance**
Production Project Manager **Clare Scott**
Senior Advertising Production Manager **Joanne Crosby**
Digital Editions Controller **Jason Hudson**
Production Coordinator **Stephen Turner**

Management
Managing Director **Dave Clutterbuck**
Commercial Finance Director **Tom Swayne**
Head of Art & Design **Greg Whitaker**
SVP Lifestyle, Knowledge and News **Kevin Addley**

Printed by William Gibbons & Sons Limited
26 Planetary Road, Willenhall, Wolverhampton, West Midlands, WV13 3XB

Distributed by Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU
www.marketforce.co.uk

ISSN 2041-7322

All contents © 2023 Future Publishing Limited or published under licence. All rights reserved. No part of this magazine may be used, stored, transmitted or reproduced in any way without the prior written permission of the publisher. Future Publishing Limited (company number 2008885) is registered in England and Wales. Registered office: Quay House, The Ambury, Bath, BA1 1UA. All information contained in this publication is for information only and is, as far as we are aware, correct at the time of going to press. Future cannot accept any responsibility for errors or inaccuracies in such information. You are advised to contact manufacturers and retailers directly with regard to the price of products/services referred to in this publication. Apps and websites mentioned in this publication are not under our control. We are not responsible for their contents or any other changes or updates to them. This magazine is fully independent and not affiliated in any way with the companies mentioned herein.

If you submit material to us, you warrant that you own the material and/or have the necessary rights/permissions to supply the material and you automatically grant Future and its licensees a licence to publish your submission in whole or in part in any/all issues and/or editions of publications, in any format published worldwide and on associated websites, social media channels and associated products. Any material you submit is sent at your own risk and, although every care is taken, neither Future nor its employees, agents, subcontractors or licensees shall be liable for loss or damage. We assume all unsolicited material is for publication unless otherwise stated, and reserve the right to edit, amend, adapt all submissions.

We are committed to only using magazine paper which is derived from responsibly managed, certified forestry and chlorine-free manufacture. The paper in this magazine was sourced and produced from sustainable managed forests, conforming to strict environmental and socioeconomic standards.

ipso Regulated

Widely Recycled

FUTURE
Connectors. Creators. Experience Makers.

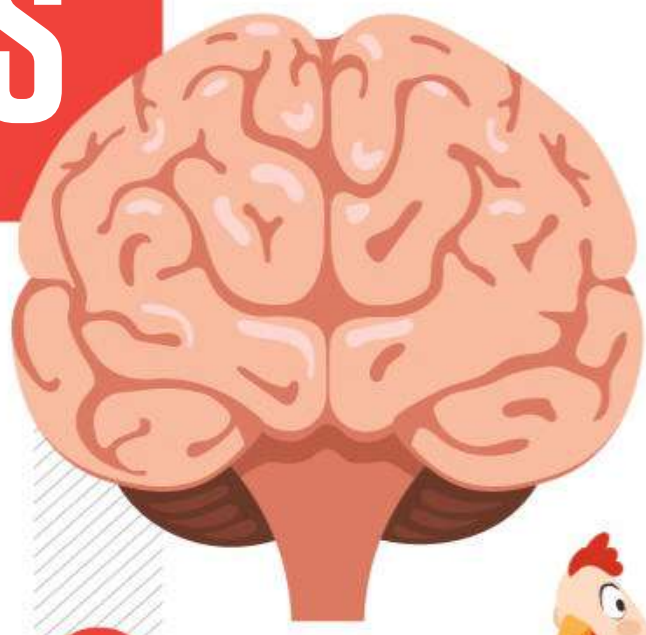
Future plc is a public company quoted on the London Stock Exchange (symbol: FUTR)
www.futureplc.com

Chief Executive Officer **Jon Steinberg**
Non-Executive Chairman **Richard Huntingford**
Chief Financial and Strategy Officer **Penny Ladkin-Brand**

Tel +44 (0)1225 442 244

FAST FACTS

Amazing trivia that will blow your mind



YOUR BRAIN CONTINUOUSLY EATS ITS OWN CELLS

100g

Fleas experience 100 times the force of gravity when jumping

18 MONTHS

In 1945, Mike the chicken lived a year and a half without its head

21 HOURS

600 million years ago, a day was three hours shorter than it is today

30X

Giraffes are much more likely to be struck by lightning than humans

Some deaf people don't sleep talk, they sleep sign

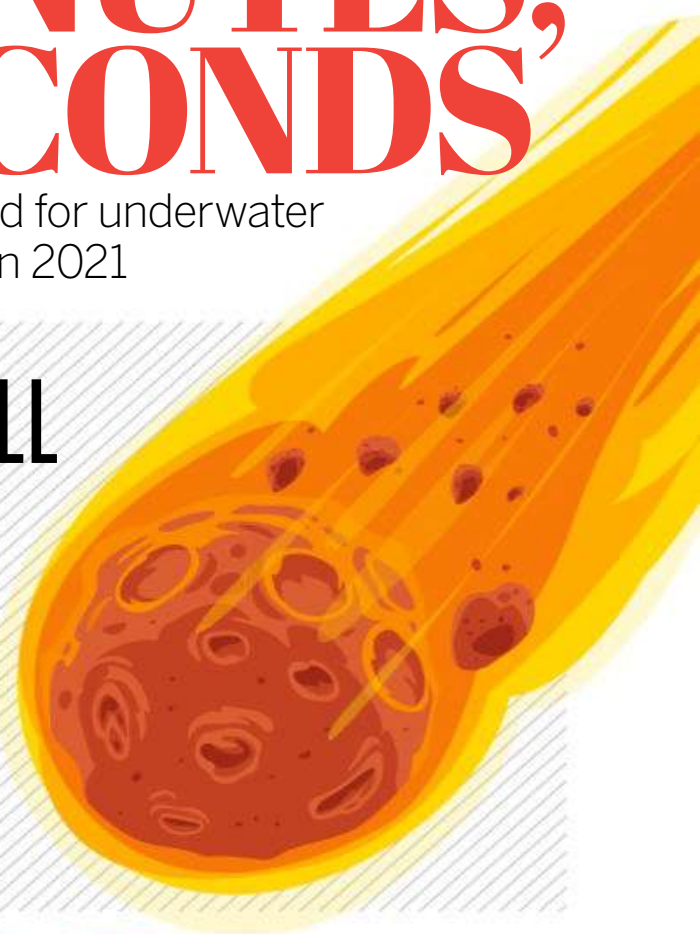
24 MINUTES, 37 SECONDS

The current world record for underwater breath holding was set in 2021

-20.6 DECIBELS

Microsoft's anechoic chamber in Washington is the quietest place on Earth

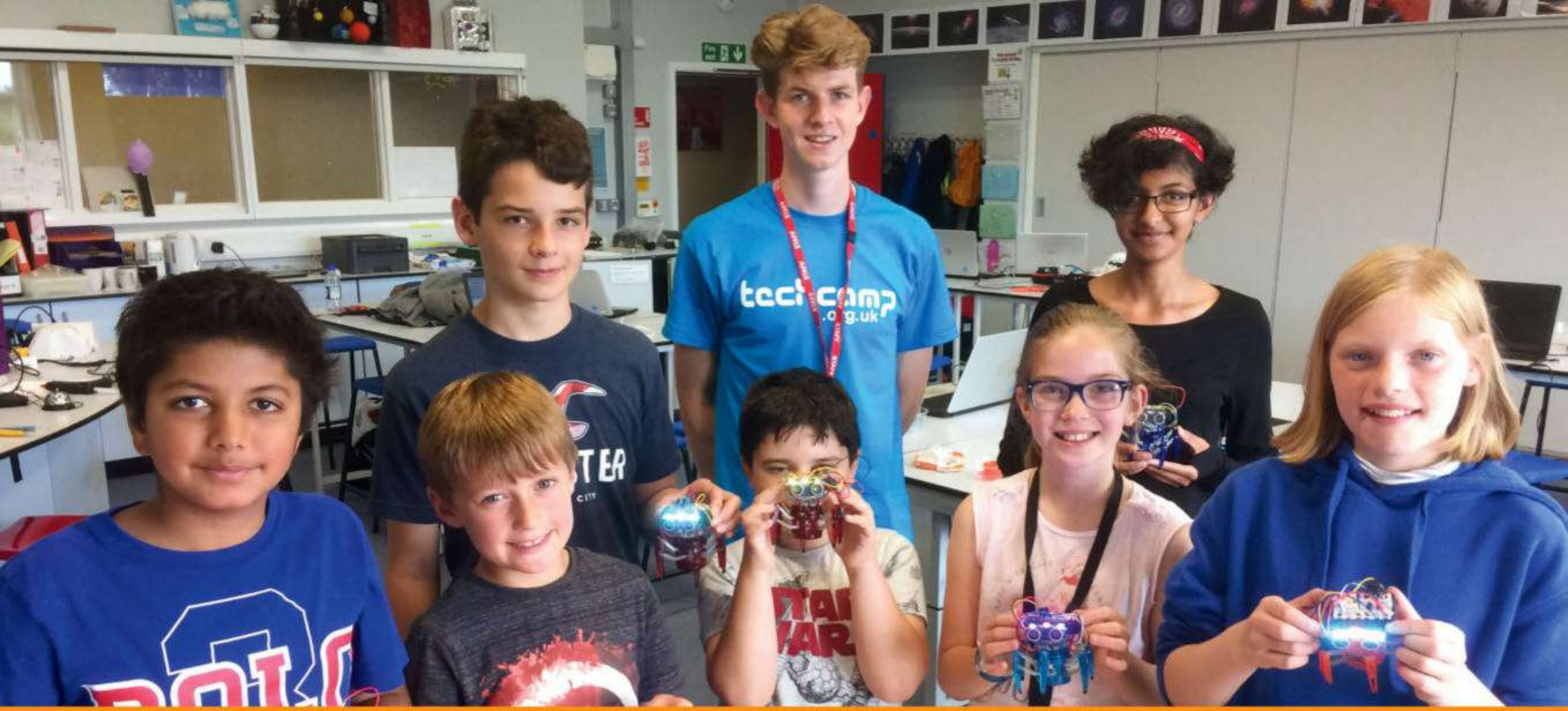
COMETS SMELL LIKE ROTTEN EGGS, URINE AND BURNED MATCHES



40 LIGHT YEARS

A relatively short cosmic distance from Earth is a planet made of diamond

© Getty



REAL ENGINEERING FOR KIDS

techcamp .org.uk

- The UK's original Tech Camp® for ages 9-17
- Week-long residential & non-residential camps
- Learn coding with real engineering projects
- Trusted for over 15 years

Bookings Now Open for 2024

Build your **Own...**

- 3D GAMES
- 3D PRINTERS
- HIGH-SPEED CARS
- DRONES
- ROBOTS
- PYTHON AI COMPUTERS

Reserve Today
www.techcamp.org.uk
+44 (0) 118 380 5678

Use Code **HIW24** for £50 Off

WHALE AND DOLPHIN CONSERVATION

WDC

From £4 a month

Adopt an orca today

Do you love orcas and want to make a super cool New Year's resolution?

This year you can help create a world where every whale and dolphin is safe and free when you adopt an orca. You'll receive a welcome pack with a personalised certificate, set of stickers, colourful badge plus a 36-page colouring book. You'll then be kept up to date with your quarterly *SPLASH!* magazine and monthly e-newsletter!

FIND OUT MORE AT ADOPTANORCA.COM

Registered with FUNDRAISING REGULATOR

WDC is a company limited by guarantee registered in England, number 27327421, registered charity number 1014705 (England and Wales) and No. SC040231 (Scotland). Telephone 01249449 500 Photos ©Charlie Phillips

9001
9000